

***A glimmer of hope?***

**I**S the government's approval of the scheme to import liquid methane from the Sahara merely another disconcerting shuffle within an aimless policy vacuum, or can we really see the first faint glimmer of an integrated fuel policy? For some time now the Gas Council has been carefully drawing up a comprehensive programme for importing natural gas from North Africa. There are abundant (and practically limitless) gas deposits in the Sahara, and the French producing companies, anxious for an outlet, have been willing to sell this gas at very favourable prices. In less than three years' time it is expected that 354 million therms of gas p.a. will be imported from the Sahara, accounting for 10% of all this country's gas requirements. The decision to import such a significant proportion of fuel from abroad, against the entrenched opposition of the coal industry, shows that the ultimate cheapness of gas to the consumer is now a guiding factor in the government's policy.

The gas will initially flow through an existing main from Hassi R'Mel gasfield (second in size to the Panhandle field in U.S.A.) to Port Arzew near Oran. There it will be liquefied in special plant to be installed by the Compagnie Algerienne de Metane Liquide. At a temperature of  $-258^{\circ}\text{F}$ . (occupying only 1/600th of its original volume) it will be transported to England in the *Methane Pioneer*. This is a converted tanker owned jointly by the Gas Council and Conch International Methane Ltd., which has already proved itself by a series of seven trial voyages from the Gulf of Mexico to Canvey Island between January 1959 and March 1960. The liquid methane will be stored in specially constructed tanks to be built by the North Thames Gas Board in Canvey Island. Subsequently, it will be pumped to regasification equipment and then transmitted through a new steel main to 7 out of 12 Area Gas Boards.

The most important (and so far unanswered) question is what the individual Area Boards will do with the methane. There is a strong possibility that the West Midlands Board will use it to enrich their Lurgi gas, once the Lurgi plant, at present under construction at Coleshill, comes into operation. The other Area Boards will probably reform the high-calorific methane to low-calorific town gas specifications. Such reforming is usually carried out in *Onia-Gegi* or *Segas* plants, using oil feed stocks. Therefore, it is likely that in future, feedstock for such reforming plants will be based decreasingly on petroleum cuts and more on natural gas.

Although Lord Robens claims that the use of this natural gas will mean a reduction of 800,000 tons coal p.a., this is just a hypothetical figure, since it

seems that the Gas Council would in any case have opted for more oil gasification plants, rather than install more of the conventional (and outdated) carbonisation plants using coal, whose price has risen much too steeply of recent years. In any case, the whole success of the gas importation scheme will depend on how soon a national grid for distributing high-pressure gas from central plants is established. The Gas Council has not yet made up its mind on this point; yet it seems that the decision to import methane is the first glimmer of an integrated fuel policy, equally fair both to the various sections of the fuel industry and to the consumer.

***Confidence in thermoplastics***

**C**ONTINUED confidence in the growth of the plastics industry was the theme of a recent Press visit to the Shell Chemical Co.'s Carrington plastics laboratory. Shell, as one of the world's leading producers and refiners of oil, were one of the first to enter the petrochemicals field, both in this country, the Netherlands and the U.S.A. Now, with the new plastics laboratory adjacent to their petrochemicals works, they are able to carry out both development and technical service in the increasingly competitive field of thermoplastics. In keeping with its function, the new laboratory has been designed to utilise, wherever possible, plastics materials of construction. Its functional, yet aesthetic appearance is proof that laboratory architects can combine both good taste with sensible layout and planning.

Shell make the three leading types of thermoplastics which account for 80% of the world consumption: vinyls, polystyrene and polyolefines. Vinyls, however, are only made by the Dutch company in Pernis; Carrington has specialised in polystyrene and, in more recent years, polyolefines. The advantage in having entered this particular field at a relatively late stage has enabled Shell to plan an integrated polyolefines complex comprising low-density polyethylene, high-density polyethylene and polypropylene. The low-density polyethylene process was obtained by Shell from B.A.S.F., who developed it from the I.C.I. high-pressure process. The high-density polyethylene and polypropylene processes were both licensed by Ziegler and Montecatini. However, process development in this comparatively new field of stereo-specific polymerisation was carried out entirely at Carrington. An enormous amount of fundamental chemical engineering studies went into this project, as is demonstrated by the impressive pilot plant which was designed to evaluate process characteristics. It is rather a pity that Shell are prevented, due to the nature of their licence agreement with Montecatini,

from also fabricating polypropylene fibres.

The thermoplastics industry is already the fastest rate-growing sector of the plastics industry. Yet, with increasing thermoplastics production capacity in the U.K., new uses and applications will have to be developed or the existing markets will become saturated. For this reason thermoplastics are now being considered very seriously in the motor-car and building industry. It is in furthering the use of plastics in such new fields that Carrington should make its most valuable contribution.

### **French isoprene synthesis**

**I**SOPRENE, now of considerable importance as raw material for cis-polyisoprene (natural synthetic rubber), is only found to a very small extent in petroleum cracking cuts. During recent years, much investigation has been devoted to designing an efficient process for producing isoprene from  $C_4$  and  $C_6$  cuts. Generally, such a process involves the Prins reaction, in which isobutylene is reacted with formaldehyde to give 4 : 4 dimethylmetadioxane, which is then decomposed in the second stage with recycle of the by-product.

The Institute Francais du Pétrole, for the last year, has been carrying out a study of the design characteristics and economics of such a process. A. Y. Giraud of the I.F.P. described this in a recent article in *Chemical Engineering Progress*, 1961, 57, 66. The advantage of this process lies in its complete integration, since formaldehyde is obtained by controlled oxidation of methanol which, in turn, can be made from natural gas. The isobutylene occurs in the  $C_4$  cracking cut, together with *n*-butane, butene-1, butene-2 and butadiene. With such a cut it should be possible to convert almost all the isobutylene without any interference from the *n*-butylenes. In most steam cracking cuts, butadiene, of considerable importance in the production of polybutadiene and styrene-butadiene, has to be removed.

In order to do this the whole of the  $C_4$  cut is sent to a dehydrogenation reactor (where alkanes are converted to alkenes) and the butadiene is then extracted from the effluent with ammoniacal copper acetate, the remainder of the solution being passed to the first stage of the isoprene process.

Here, isobutylene is contacted with formaldehyde solution and an acid catalyst in a countercurrent absorption tower. At the outlet of the absorber, the organic phase is flashed to recover any unconverted  $C_4$ . The dioxane formed is separated under vacuum from the heavier by-products and is catalytically decomposed in a moving-bed reactor. Effluent from the reactor settles, after cooling, into an organic and an aqueous layer. The organic layer is fractionated by distillation to give isoprene, isobutylene, unconverted dioxane and a small quantity of by-products.

An estimate for a 40,000-tons-p.a. isoprene plant was calculated by the author to cost \$11.2 million. The selling price was fixed at 10.8 cents/lb., and hence one year's production would amount to \$10 million—within the bounds of economic profitability.

### **Corrosion**

**I**T is perhaps preaching to the converted when pointing out the enormous wastage of corrosion in all spheres of industrial and domestic life. Estimated losses of £600 million p.a. due to this hazard only underline the seriousness of this national problem. Like sin, we are all against corrosion, but unfortunately often fail to understand its basic causes and are therefore prevented from applying effective counter-measures.

In the special feature on corrosion this month we are publishing one article dealing with the fundamentals of corrosion—with particular reference to chemical engineers. The author of this article, H. A. Holden, has reviewed various mechanisms of corrosion and how these apply to corrosion of chemical plant and materials of construction. It is impossible to discuss this subject fully in a single article, but the extensive bibliography included will help the reader to delve further into this whole field. Two common methods of preventing corrosion in chemical plant are discussed in further articles. D. A. Shingleton writes on the importance of epoxide resin paints, a fairly latecomer to the whole field of corrosion-resistant paints, and still unfortunately quite expensive. A. D. MacLennan in an article on zinc coatings, part of the series on 'Materials of Construction for Chemical Plant', discusses the growing use of zinc coatings for steel plant. A considerable industry has grown up dealing with zinc coatings and it is certainly one of the most effective and economic means of protecting plant against certain types of corrosive environments.

### **Strontium-90 recovery**

**O**NE of the most persistent and dangerous radioactive fission by-products is undoubtedly strontium-90. Hitherto this isotope has always been considered valueless; the main task of fission recovery plants has been to isolate and bury such strontium wastes. Recently, however, the U.S. Atomic Energy Commission has undertaken to make available to industry large quantities of useful fission products, for fabrication into batteries and other devices. For example, in January 1960, the A.E.C. announced its need for nearly 1 million curies of strontium-90. Nuclear batteries could serve as power sources in space vehicles, unmanned weather stations, etc. Strontium-90, which is a strong beta emitter and a long-lasting source of heat energy, can be converted into low-watt electrical power.

Another by-product programme involves the recovery of caesium-137 from stored radioactive wastes and shipment to Oak Ridge for purification and formation into capsules. The caesium capsules are good sources of gamma radiation and will be sold to medical establishments for use in research and radiotherapy.

The recovery of strontium-90 and caesium-137 is carried out by taking the fuel elements (after fission) to the Hanford purex chemical separation plant, for isolation of the plant's primary end-product plutonium,

as well as any remaining uranium from the fission by-products. The crude strontium is first recovered from the production streams by batch precipitation in the purex plant. After ageing, it requires extensive purification to meet the high standards necessary for its use as a heat source. This is at present being done in the Hanford high-level radiochemistry laboratory by means of ion exchange. Eventually, large-scale strontium purification will be carried out at the hot semi-works.

### **International Atomic Energy**

**I**T is a great pity that the cold war has finally permeated into the arena of the International Atomic Energy Agency. The Agency, which forms part of the U.N., was founded to promote the peaceful uses of nuclear energy and thus to try and bridge the political differences that have polarised the world into two hostile camps. After all, science has mainly thrived in this century because of its international language and reliance on objective verifiable evidence. Mr. Sterling Cole, the retiring Director-General of the I.A.E.A., in his last address to the General Conference held in Vienna recently, surveyed the progress made since the beginning of the Agency.

At its initiation in 1957, it was expected that the major powers would use the new force of atomic energy to improve the lot of mankind in the less-developed areas of the world and to place less emphasis on weapons. Although this optimism has been excessive, some programmes in the peaceful field are now beginning to bear fruit.

Firstly a successful fellowship programme has been carried out which has trained over 380 students to assist in atomic energy development in their own states. Early in 1958 the I.A.E.A. initiated technical assistance programmes which included the provision of experts, equipment, visiting professors and training courses. These programmes have unfortunately had to be dropped because of lack of funds to meet those needs.

The Agency's programme for promoting research and development into the peaceful uses of atomic energy has steadily evolved during the last four years. Contracts of approximately \$800,000 were placed with member states in 1959 and 1960 to encourage research in the safe disposal of radioactive wastes, health physics, radiation protection, radiobiology and isotope applications.

Mr. Cole concluded his address by suggesting possible objectives which the Agency might try to aim at during the next few years. A long-term programme could be evolved which would leave room for bold new ideas, such as participation in a large international accelerator or power reactors or a possible Institute of Theoretical Physics. In order to carry out such ambitious programmes the dependence of the Agency on voluntary contributions is a useless and frustrating operation. For this reason an improved method of financing must be found whereby more of the Agency's activities can be paid under the regular budget obtained by assessments from member states.

### **Graduate emigration—a danger?**

**T**HE spectre of graduate emigration has once again been raised in the readership columns of *The Times*, by Prof. Ball (metallurgy) and Profs. Mott, Frisch and Pippard (physics). As heads of departments of pure and applied science, these scientists are in a unique position to judge the problem from personal experience. They are naturally concerned with the depletion within the ranks of their own teaching and research staff, due to the enticement of their best brains by American universities and research organisations.

According to Prof. Ball, the young graduate is mostly concerned with attaining the higher standard of living that the United States can offer him (patriotism and loyalty to one's own country definitely plays a secondary role). He quotes the example of a recent London Ph.D. scientist who, within ten days of taking up his position in the U.S.A., was installed in a modern flat with every conceivable labour-saving device and, in addition, had acquired a mammoth-sized car. It was generally felt by potential emigrants that they would not only raise their standard of living but, and this is even more important, they would have money allotted for scientific projects. Profs. Mott, Frisch and Pippard even raised the fear that in 10 to 15 years' time there would be a serious shortage in candidates for the highest academic offices, due to this depletion!

Although not everyone familiar with this problem would agree with these gloomy forebodings, there is certainly a considerable amount of justification for them. Does this emigration danger apply equally to chemists and chemical engineers? Probably not, because of the rapid internationalisation of the chemical industry. Many companies, whose headquarters are in the U.S.A., have established European subsidiaries which employ British chemists or engineers, rather than import them into the U.S.A. Yet the fact remains that the U.S.A. does offer higher financial inducements as well as making the graduate feel that he is part of a technological 'elite'. It may be well for us to note this trend very carefully before it is too late.

### **British oilfields**

**M**OST textbooks generally inform us that oil was first struck in 1859 in Pennsylvania by the eccentric Col. Drake. That this date denotes the beginning of the enormous American oil industry is indisputable, yet in Britain oil had been worked on a modest scale for many years prior to Col. Drake. In medieval times, for example, tar springs were used for medicinal purposes and pitch was already being worked by the Romans. Much later, waxy oil, seeping through the Midlands mines, was often used for greasing the axles of colliery wagons.

Oil refining in Britain actually dates back to 1850 when the Scotsman, Alexander Young, erstwhile student of Joseph Black, obtained oil by distilling cannel coals and shale. At that time his outlook and



ideas were considered somewhat futuristic, and although modestly successful on a financial scale, he failed to persuade the government that there was any particular importance inherent in this black, viscous liquid. More than a century later, we are apt to forget that oilfields not only exist in this island but are actually being worked. Until the 1914 war any possibility of oilfields occurring in Great Britain was neglected, but due to the submarine menace at that time, a search for petroleum was initiated.

As a result, one small oil well was discovered in Derbyshire. Following the Petroleum Production Act of 1934 the ownership of all oil not discovered up to that date was vested in the crown. Thus companies could acquire exploration licences over large areas under attractive operating conditions. The first major oilfield was discovered by the D'Arcy Exploration Co. Ltd., later renamed the B.P. Exploration Co., in Portsdown in 1936. Since then, oilfields have been opened in various parts of the country, particularly in Nottinghamshire. During 1959 the total oil produced from British fields (most of which are owned by B.P.) amounted to 1.2 million tons.

It is confidently expected that, by the application of modern drilling techniques, further oilfields will be discovered, particularly in the West Midlands, South of England and in Scotland. Although it would be a pipe dream to expect that Britain will ever attain self-sufficiency as regards her oil needs, indigenous oil may well provide an increasing percentage of total British requirements in future years.

### ***Versatile research projects***

A GREATER emphasis on sponsored projects to be paid by industrial undertakings, is a major aim of the Warren Springs Laboratory. Just over a year after its founding, the annual report points out that during 1960, 22 different repayment projects were undertaken. Six of these investigations were concerned with U.K. mineral deposits, whilst the remainder, dealing with overseas deposits, were carried out on behalf of various British companies, the U.K.A.E.A. and the Colonial Office.

Warren Springs seems to embrace a variety of activities that would be considered 'odd man out' in other D.S.I.R. research establishments. The department of atmospheric pollution, for example, is currently making a survey in co-operation with local authorities to provide accurate information about smoke and SO<sub>2</sub> pollution throughout the country. Pollution measurements are being made at selected sites in representative towns and data already obtained show some interesting trends. For example, from 1952 to 1959 smoke emission over the country as a whole decreased from 2.3 to 1.9 million tons. In London from 1953 to 1959 smoke emission was reduced from 152,000 to 82,000 tons.

As was pointed out in these columns last year (CPE, 1960, 41, 433) work on the synthesis of oil from coal is being discontinued at Warren Springs. However, allied work on catalysis is continuing and last

year, an investigation was carried out into the relation between electric properties and catalytic activity of iron oxide containing small concentrations of titanium dioxide. In the chemical engineering division, basic research is carried out on bubble formation with particular reference to distillation and gas absorption. Up to date, several excellent papers have been published by members of this division (mostly at last year's International Distillation Symposium in Brighton).

It may perhaps be timely at present to inquire what precise tasks are foreseen for the chemical engineering division. There seems little point in carrying out fundamental chemical engineering research on subjects that are being catered for by university departments. Surely here is a nucleus for a potential Chemical Engineering Research Association, to serve the needs of a very broadly based industry on a contract basis. There is a serious need for such an association.

### ***The old and the new***

ONCE again Christmas is in the air and we stand on the threshold of a new year. Unfortunately, the old year has done nothing to bring us any nearer to the Christmas spirit of 'peace on earth and goodwill towards men'. International tension has increased and peace on earth seems as remote as ever. Let us hope that the new year may see at least some abatement of this perpetual tension. We in our own way try to further international understanding by spreading technical information throughout every country of the world. The language of science and technology is international; and it may be that by increasing the rate of communication in these disciplines, people will gradually become aware of what they have in common—rather than what separates them.

CPE has endeavoured throughout 1961 to cater for the interests of all readers, dispersed as they are throughout the chemical, process and nuclear industries. It is often difficult for a practising engineer to devote sufficient time to keep up with developments in a broadly based industry. By publishing articles that are factual, informative and original, we extend a service that helps our readers to keep abreast of current developments in chemical engineering.

One innovation, with which we shall start the new year, will be the publication of a bi-monthly supplement to CPE called 'The Cost Engineer'. Cost engineering, defined as the application of scientific principles and techniques to problems of cost estimation, cost control and profitability, is of paramount importance to a wide range of engineering industries and particularly to the chemical and process industries. 'The Cost Engineer' will form the official proceedings of a recently constituted association called the British Section of the American Association of Cost Engineers. It is with some considerable pride that we announce the appearance of the first British publication on cost engineering. In this way we hope that our readers can gain an authoritative insight into an increasingly important branch of the industry.



# Metallic Corrosion—Some Chemical Engineering Aspects

By H. A. Holden,\* M.Sc., A.R.C.S., D.I.C.

*The applied science of corrosion prevention has made considerable progress during the last decade. The chemical engineer, faced by the ever-present hazards of corrosion, will find this article particularly useful, since it discusses fundamental corrosion concepts such as oxidation, electrochemical corrosion inhibitors, galvanic corrosion, acid corrosion, atmospheric corrosion and intergranular corrosion. Appropriate literature references are made throughout the article.*

THE scientific and technological fields covered by the terms 'corrosion and corrosion protection' are now very extensive and, in consequence, the relevant literature has increased rapidly, particularly since the last war. To take but two simple examples of this, what is undoubtedly the standard work, namely 'The Corrosion and Oxidation of Metals' by U. R. Evans,<sup>1</sup> which was published in 1960, contains over 1,000 pages and an author index of some 3,000 names, and the papers presented at the First International Congress on Metallic Corrosion,<sup>2</sup> held in London in May this year, occupy over 500 pages.

as complex heterogeneous bodies consisting of many phases, all capable of developing different corrosion couples, brought their somewhat different approach to academic corrosion research. Further, in addition to these interests of the pure scientist as physical chemist, electrochemist, physicist or metallurgist, in recent years there has been an increasing amount of applied corrosion research which is often technological rather than fundamental. In many cases this has been either carried out by, or is of direct interest to, engineers and chemical engineers, and largely devoted to corrosion prevention. This field has

some of the fundamental concepts which seem to the author most likely to assist chemical engineers with their corrosion problems, and to indicate with appropriate literature references where more detailed up-to-date information can be found.

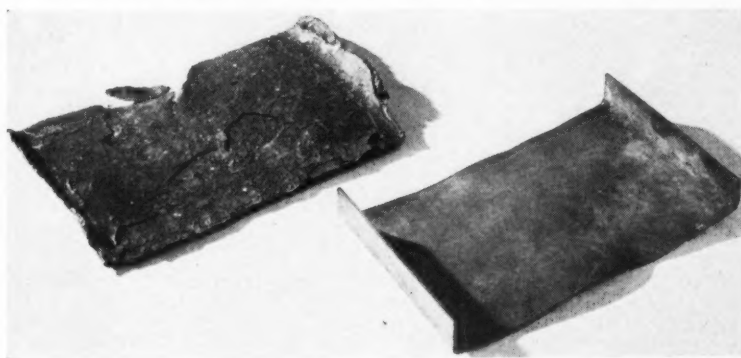
## Definition

Corrosion is defined by Evans<sup>5</sup> as 'the destruction of metal or alloy by chemical change, electrochemical change or physical dissolution'. The combination of metals with oxygen is a simple example of chemical change and, although some authorities do not consider oxidation to be a form of corrosion, in view of its important engineering aspects it will be considered to be so as far as this article is concerned.

## Oxidation

Generally speaking, oxidation of metals in air takes place quite readily at high temperatures, but at room temperature the oxide film soon isolates the metal from the air and, in dry pure air at any rate, the rate of oxidation becomes negligibly slow, even before the oxide film becomes visible. In reasonably pure air, therefore, direct oxidation at room temperature is relatively unimportant as a corrosion mechanism.

At these low temperatures, however, electrochemical corrosion requiring the presence of water and often producing hydroxide rather than anhydrous oxide comes into operation. If the corrosion product is not formed as a protective film but as a loose precipitate which



[Courtesy: Thor Tools Ltd.]

Fig. 1. Trays used for hardening machined spindles at 950°C. in gas-fired furnaces

Whereas 20 years ago most of the research on corrosion was carried out by physical chemists—mainly electrochemists who treated corrosion reactions from the classical standpoint—it was only after the war that metallurgists began to pay increasing attention to corrosion. In particular, metal physicists, who view metals and alloys

become so important that in this country there are now two journals<sup>3</sup> devoted solely to the technology of corrosion and its prevention, and a third journal covering more academic considerations has recently commenced publication.<sup>4</sup>

Faced then with this mass of data, the most that can be done in a short article is to present current views on

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does not stifle further attack, corrosion once started could continue indefinitely.

Oxidation mechanisms at elevated temperatures have important chemical engineering implications, for as the oxide film grows so it progressively protects the metal from the oxygen and the rate of growth is often controlled by the passage of either metal (outwards) or of oxygen (inwards) through the solid film, passage through the film depending essentially on lattice defects. Chemical engineers would clearly prefer to use a material on which oxidation stifles itself before there is a serious loss of thickness and strength. Unfortunately, however, the thicker the scale the more liable it is to damage and, for high-temperature work, development has been towards the production of materials on which the oxidation rate becomes slow when the scale or film is still relatively thin.

Fig. 1 shows trays used for hardening machined spindles at 950°C. The mild-steel tray was withdrawn from service after 600 hr. The *Incoloy* DS tray has already done 2,000 hr.

Much fundamental research has been carried out on the oxidation of pure metals, with particular reference to film growth laws and composition of the films, but generally speaking, whilst this is of considerable academic importance, it is only of practical significance to the chemical engineer for very specialised conditions. Chemical engineers seldom use pure metals as materials of construction for operation under these conditions. It is important to consider, therefore, the effects of an additional constituent(s) in one or other phase, i.e. as an intentionally introduced alloy constituent or in the atmosphere to which the metal is exposed.

A minor constituent in the metal phase can influence oxidation in two ways, depending on whether it can distribute itself in the main oxide phase or, alternatively, the minor constituent may introduce a new phase at the base of the oxide layer. In the first case, velocity of film growth may be accelerated or retarded but usually the growth law will remain the same. In the second case, however, changes may be more drastic as, for instance, the parabolic growth law may give place to a log-law shape which, from the engineer's standpoint, is usually desirable. Practical applications of these principles are, for example, the addition of chromium, aluminium and silicon to steel for high-temperature corrosion resistance. In addition to high-temperature performance, how-

ever, mechanical properties have also to be taken into consideration and, fortunately, many alloy constituents favoured for improvement in mechanical properties tend to improve oxidation resistance, with the possible exceptions of molybdenum and vanadium. Under certain conditions, particularly associated with the presence of vanadium in the scale derived from the ash of fuel oil, extremely rapid corrosion can occur—so-called 'catastrophic oxidation'.<sup>6-9</sup>

In order to anchor the oxide film and reduce the danger of flaking, especially under conditions of fluctuating temperature, a limited amount of penetration along grain boundaries, etc., is beneficial. Excessive penetration, of course, would weaken the material. This is known as 'pegging-in', but must be carefully controlled and the addition of pegging-in constituents must be regulated to provide sufficient but no excessive anchorage. Examples of the successful application of the pegging-in principle are the nickel-chromium alloys used for electrical resistance furnaces and other high-temperature applications.<sup>10</sup>

### Electrochemical corrosion<sup>11</sup>

It has now been established beyond any doubt that the great majority of corrosion processes have an electrochemical mechanism and many of the corrosion problems encountered by the engineer can be explained on this basis.

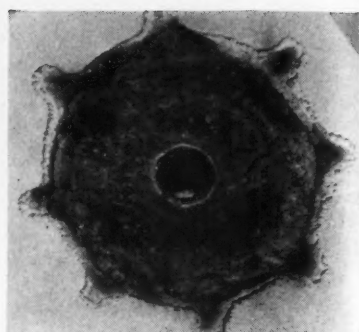
Whereas 'simple oxidation' is operative at elevated temperatures, at low (room) temperatures it is 'wet' corrosion which is important. In essentials, this is dependent upon the flow of an electric current between anodic and cathodic areas which are sometimes well separated. Metal is thus converted to oxide, hydroxide or basic salt and, if no stifling film is produced, relatively rapid corrosive destruction can occur.

The example frequently quoted in the textbooks is the case of zinc immersed in potassium chloride solution. If a zinc specimen is partly immersed in potassium chloride solution, the lower portion is soon attacked and there is usually a zone just below the water-line which remains unattacked.

Immediately below the water-line, oxygen from the air uses up electrons in the 'cathodic reaction', which may be simply expressed as:



As a result of this, metal can enter the liquid lower down the specimen as



[Courtesy: International Nickel Co. Ltd.]

Fig. 2. Magnesium cast around steel core, illustrating galvanic action

cations and the following anodic reaction occurs:



If (a) and (b) occur at the same rate, no electric charge will accumulate and, as the cathodic and anodic products are potassium hydroxide and zinc chloride respectively, which are readily soluble, no film can be formed over the lower surface and corrosion continues unimpeded.

Such corrosion currents can be brought about in different ways. If two different metals are in metallic contact, one will be anode and the other cathode, giving rise to 'galvanic' or 'dissimilar metal corrosion' and, in the case of the zinc in potassium chloride, there is better replenishment of oxygen at the surface of the liquid, thus giving rise to 'differential aeration currents'.<sup>12</sup> Often the strength of the current is controlled by the supply of oxygen to parts where the cathodic reaction can proceed. A reduction in oxygen availability therefore diminishes corrosion.

### Inhibitors

An essential condition of continuous electrochemical corrosion attack is, of course, that both anodic and cathodic products shall be freely soluble. If a salt added to the solution results in an insoluble substance being produced by the anodic or cathodic reaction, such added materials are known as anodic or cathodic inhibitors. As a broad generalisation, the film produced by a cathodic inhibitor is usually visible and can be scraped off, whereas anodic inhibitors produce thin, invisible films—at least when they are in contact with the metal. Inhibition may, however, sometimes be experienced where soluble products are expected; also, even if the inhibitive properties of a chemical have been established, it may do more harm than

good if used in insufficient quantities. At one time, considerable importance was attached to this distinction between cathodic and anodic inhibitors, as the former, although less efficient than anodic ones, were believed to be safer in that they did not tend to localise any corrosive attack which occurred. This belief is, however, now losing favour.

Chromates and nitrites are commonly used in industry to inhibit corrosion, in particular attack on iron in aqueous solution. Both are oxidising agents, but it is now fairly well established that their inhibiting properties are not solely due to their oxidising power. Agreement has not yet been reached on the complete mechanism of inhibition by chromates and nitrites, but it is undoubtedly associated with protective film formation. The main constituent of the film formed on iron after immersion in a chromate solution is cubic iron oxide.<sup>13</sup> The amount of chromate in the film is greater if oxygen is present in the solution. Nitrites also produce a cubic iron oxide protective film.<sup>14</sup>

In the presence of chloride, corrosion, if it starts with water which has been treated by chromate and nitrite, will most probably take the very dangerous form of pitting. These inhibitors must therefore be added in ample amounts.<sup>15</sup> Further, if any corrosion products containing ferrous compounds are formed, they will react with and destroy the inhibitors.

Calcium bicarbonate is a cheap and efficient inhibitor for water supplies. It is present in most hard waters, but protective films of chalky rust are

only formed if the carbon dioxide content is limited to that necessary to stabilise the bicarbonate, so that the smallest pH increase makes the liquid next to the metal supersaturated with calcium carbonate. Hence the advantage of cascading to remove 'aggressive' carbon dioxide and introduce oxygen.

Generally speaking, for adequate protection there should be sufficient oxygen to convert ferrous to less-soluble ferric compounds at a point close to the metal and thus form a corrosion-stifling protective film.

Other widely used inhibitors are the proprietary *Calgon* and *Micromet*, which are condensed phosphate materials and have particular industrial applications for corrosion inhibition in moving waters. This should be borne in mind when designing water systems for water passing through a plant. They also are believed to act by depositing a film on the cathodic part of the surface.<sup>16, 17</sup> For technical advice regarding inhibitive water treatments, reference should be made to the books on the subject.<sup>18</sup>

### Galvanic corrosion

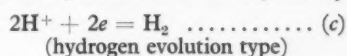
Serious corrosion often occurs when two dissimilar metals are in contact either directly or through an electrolytically conducting liquid. The 'base' or anodic metal suffers special corrosion, and attack on the 'noble' or cathodic metal is sometimes diminished. This type of corrosion has been known for a long time and, as its name implies, is due to a galvanic cell which will usually generate a much stronger current than, say, a differential aeration cell with both electrodes of the same metal. Although substantially correct, this explanation is not without its exceptions, and many cases are known where, in service, contact between dissimilar metals has caused no special damage. Indeed, as a practical guide to combinations of metals which will stimulate attack on the base metal providing protection to the more noble, as indicated by this simple explanation, the table of normal potentials has proved of very limited value. Instead of discussing complicated electrochemical arguments—which must involve some differences of opinion—in an attempt to help the engineer-designer facts based on practical experience have been collected together in a table<sup>19</sup> which shows at a glance whether the corrosion of one material is increased by contact with another. This is a most valuable document for all chemical engineers

and, although it cannot cover every case, it is authoritative. Galvanic action is shown in Figs. 2, 3 and 4. Fig. 2 is a specimen of magnesium cast around a steel core. Magnesium has suffered corrosion, whilst the steel is hardly affected. Fig. 3 shows the influence of area relationship between cathode and anode, illustrated by copper steel samples after immersion in sea-water. Fig. 4 shows the location of anode and cathode areas on an iron nail partially plated with zinc.

Galvanic corrosion can, of course, be prevented by insulating the metals from each other. For example, where plates have to be bolted together, consideration should be given to specially designed bushes and washers. Soldered and welded joints are other possible sources of galvanic corrosion in that different metals are in contact. The main danger of corrosion from soldering, however, is probably due to the hygroscopic residues from fluxes (mostly chloride containing), which should not be allowed to remain on the surface. In welded joints the electrochemical differences are probably less than with soldering, but the presence of internal stresses resulting from welding may increase the tendency for corrosion and corrosion cracking. In many cases, suitable heat treatment to reduce this stress does reduce or overcome such corrosion cracking.<sup>20, 21</sup>

### Corrosion by acids

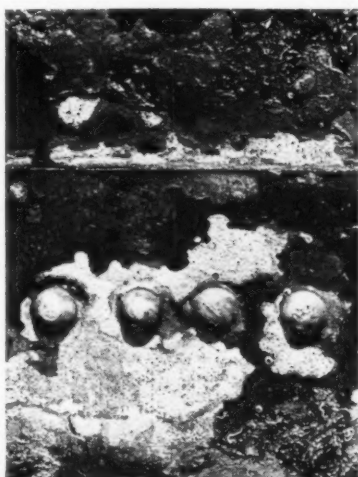
In the type of 'wet' corrosion dealt with so far, the main cathodic reaction has been the reduction of oxygen (equation (a)). There is, however, another alternative, namely



The e.m.f. driving this type of attack is less than that for (a) and, if oxygen could be replenished quickly, its reduction would be the most probable reaction. In acid solutions, however, the hydrogen evolution type also occurs quickly, and since the oxygen replenishment rate is usually too slow, hydrogen evolution usually predominates.

Conditions for hydrogen evolution are normally (i) where the metal has a very negative normal electrical potential, (ii) where a high hydrogen ion concentration exists in the liquid, i.e. in acids, and (iii) where complex ion formation keeps the normal cation concentration low, i.e. zinc and aluminium in alkaline solutions.

A different type of corrosive attack is produced by oxidising acids or



[Courtesy: International Nickel Co. Ltd.]

Fig. 3. Influence of area relationship between cathode and anode, illustrated by copper steel couples after immersion in sea-water



when an oxidising agent is added to a non-oxidising acid. In these cases the working e.m.f. is higher than that associated with the oxygen reduction type of cathodic reaction and, if attack occurs, this may be violent. As a further complication, nitric acid and concentrated sulphuric acid, being of course strong oxidising agents, may also produce films on the metal surface which, under certain conditions, particularly in concentrated acid, can give protection.

As a broad generalisation, noble metals such as gold, platinum, silver, copper, etc., do not liberate hydrogen when placed in acid, whereas the base metals standing below hydrogen in the normal potential series can do so. Reactions such as hydrogen evolution from zinc and steel in acid solutions or from aluminium in caustic soda are well known and need no amplification here. Attack by oxidising acids are, however, of considerable importance, particularly nitric acid.

Metals like magnesium, aluminium and zinc, which evolve hydrogen from hydrochloric acid solution, react with nitric acid to form ammonium nitrate or a hydroxylamine salt. Magnesium and zinc are readily attacked, but on aluminium the oxidising properties of nitric acid build a protective film which is slowly dissolved by acids. This reaction is so slow that aluminium vessels can be used for storing the concentrated acid, although there is more attack in dilute acid.

More noble metals like silver and copper, which cannot liberate hydrogen from hydrochloric or sulphuric acid, are unlikely to produce hydrogen by reaction with nitric acid. The removal of atomic hydrogen, however, by interaction with nitric acid can provide a reaction which has certain 'auto-catalytic' properties and which can be accelerated by the corrosion products.

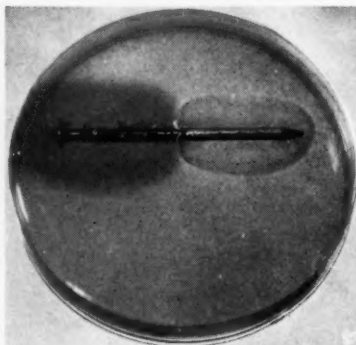
Iron behaves in a peculiar way of its own and can produce both salts of ammonia or hydroxylamine (*i.e.* as a base metal) as well as compounds rich in hydrogen (*i.e.* like a noble metal). Concentrated nitric acid produces a film on iron surfaces which renders them passive, but for practical purposes this cannot be relied upon, as occasionally it breaks down and violent attack develops. Similarly, whilst dilute sulphuric acid possesses oxidising properties and produces a protective passive layer, steel and cast-iron panels are commonly used for containing fairly concentrated acid (above 68%).

Turning now to materials for resisting special corrosive conditions and,

in particular, those involving strong acids and alkalis, it is believed that the resistance of iron-nickel-chromium alloys towards acids is due to the presence of oxygen or other oxidising agents in the liquid. This explains why corrosion sometimes occurs at inaccessible crevices. The function of chromium may well be to provide a film which can resist dissolution by a reduction process, provided either oxygen or an oxidising agent is present,<sup>22</sup> and much research has been carried out on the isolation and study of the invisible films on stainless steels. These are generally found to contain the metals in a different proportion to that in which they exist in the alloy.<sup>23, 24</sup> In selecting a material to withstand an acid, alkali or other chemical, its behaviour will vary depending upon a great variety of physical conditions, such as rates of solution flow, presence or absence of water-lines and applied or locked-up stresses, etc. These factors should be taken into consideration when consulting the extensive literature<sup>25</sup> which has now been built up on metals for use under specific conditions of service. Many standard tables now exist showing the resistance of a wide variety of materials of various industrial chemicals and these are based on practice rather than theory.

#### Atmospheric corrosion<sup>26</sup>

To the purist, atmospheric corrosion can be divided into three types, namely



[Courtesy: International Nickel Co. Ltd.]  
Fig. 4. Location of anode and cathode areas on an iron nail, partially plated with zinc

dry, damp and wet. The first has already been considered very briefly under oxidation and involves the formation of films of oxide on metals at ordinary temperature in the absence of atmospheric pollution. The second needs the presence of water vapour in concentrations above the so-called critical humidity and also traces of gaseous or solid pollution. The third, which is that normally encountered by

the engineer, requires exposure to rain or other sources of water. Reference should be made to the classical work of Vernon in establishing the principle of critical humidity in damp atmospheric corrosion and the effects of atmospheric pollution, in particular the part played by dust in the indoor rusting of iron.<sup>27</sup> As far as the engineer is concerned, it is the prevention of atmospheric corrosion rather than its causes which is of particular interest, and the most recent data regarding the behaviour of different types of metals and protective systems in this country are to be found in the sixth report of the Corrosion Committee.<sup>28</sup>

Much of the corrosion in buildings can be overcome by suitable design, and Hudson and Wormwell<sup>29</sup> have quoted many examples where the formation of bulky corrosion products in crevices has led to bulging and sometimes to failure. The avoidance of corrosion in structures may well depend as much on design as on choice of materials.<sup>30, 31</sup>

Another type of crevice corrosion of equal importance to the chemical engineer is that occurring under conditions of complete immersion and not on buildings. Its principal cause is the slow replenishment of oxygen—or some inhibitive chemical—in the recesses of a crevice and is most likely to occur with materials which, under conditions of adequate oxygen supply, develop highly protective films, *i.e.* stainless steel, titanium and aluminium.

Permanent protection is normally afforded by the application of paint or non-ferrous metallic coatings. Paint is so misused that the fundamentals of good painting practice cannot be over-emphasised.

The sole function of a coat of paint is not to exclude from the metal the water and oxygen needed for rusting. In fact, Mayne<sup>32</sup> believes that 'paint films are so permeable to water and oxygen that they cannot inhibit corrosion by preventing water and oxygen from reaching the surface of the metal'. A considerable amount of work has been carried out on the passage of water and other substances through paint, but current thinking is that the object of painting is to prevent the initiation of corrosive attack rather than slow down corrosion which has already started. How then does a paint postpone the start of corrosion on metal surfaces? It has been suggested by Mayne that an inert paint, *i.e.* one which does not contain or produce inhibitive substances or pigments, is due to low ionic conductivity.<sup>33, 34</sup>

Inhibitive pigments are often added to paints and, for them to be effective, they must be slightly but not excessively soluble. Chromates in particular are widely employed, the theory being that, since chromates are powerful corrosion inhibitors, the water passing through such a paint film will become non-corrosive. An inhibitor or corrosion stiffer may also be formed by reaction proceeding within the paint film, i.e. oil paints pigmented with lead or zinc salts may produce lead or zinc soaps which produce inhibitive substances by their degradation.

Before painting iron and steel for atmospheric exposure, removal of all scale and rust is desirable, but this should not be done by methods based on weathering. Mechanical and chemical methods are available and on light gauge material the metal should be pretreated, preferably using one of the proprietary phosphate processes. Having removed millscale and rust and pretreated the iron or steel, paint should then be applied, under good conditions, of adequate thickness and in accordance with the manufacturer's instructions. This may sound most obvious, but most of the cases of paint failure are not due to poor paint but to incorrect surface preparation or application of the paint.

### Intergranular corrosion and corrosion fatigue

Another important type of corrosive attack which may occur with certain materials, in particular zinc-aluminium die-casting alloys exposed to steam or salt-laden atmospheres, is that which is concentrated at the grain boundaries—so-called 'intergranular corrosion'. It is not entirely caused by discontinuities in the crystal structure, as the presence of impurities has been found to influence its occurrence by producing an electrochemical difference between grain boundaries and grain bodies. Intergranular attack by working inwards between the grains of the metal causes a greater decrease in strength than if the same metal loss were uniformly distributed.

Intergranular corrosion is, however, less dangerous than stress corrosion which occurs where stress acts continuously in a corrosive environment, producing cracks along a few paths only—not necessarily intergranular paths. It is a serious problem with a limited number of materials (unfortunately some of these are particularly valuable to the engineer) and then mostly after incorrect heat treatment. It is most frequently found in some

aluminium and magnesium alloys and stainless steel.

A potential difference between the grain boundary zones and interiors is probably necessary for stress corrosion to start and this has been demonstrated.<sup>35</sup> In some cases of stress-corrosion cracking hydrogen is certainly formed and, if atomic hydrogen diffuses into the metal and becomes converted to molecular hydrogen, the pressures so produced could accelerate the crack formation. A further possible explanation of the spread of corrosion cracking is that the stress keeps breaking the film at the bottom of a crack.

In contrast to stress corrosion, which is only encountered with certain materials, corrosion fatigue produced by alternating or fluctuating stresses in a corrosive environment can occur on almost any corrodible material. In discussing the cause of this comparative newcomer to the various types of corrosion, Evans<sup>36</sup> points out that corrosion of disarranged material occurs more readily than with a perfectly arranged material and occurs more quickly at high than low temperatures. Both these conditions exist along the gliding planes under fatigue conditions and it is not surprising therefore that, at a 'stress-range' where, for practical purposes, only elastic changes would occur in the absence of corrosion, relative movement continues—ultimately leading to crack formation—if corrosive influences are present to destroy the interlocking material which would otherwise hold up gliding and substitute elastic deformation'. Much remains to be learned regarding the measures to be taken for overcoming corrosion fatigue, but current practices include the use of paint films, anodising, electroplating and shot-peening under certain specific conditions.

### ACKNOWLEDGMENT

All the principles outlined are dealt in greater detail in U. R. Evans' excellent book 'The Corrosion and Oxidation of Metals' and due acknowledgment is made to the great help this has been in the preparation of this article.

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### Industrial boilers

The British Standard dealing with acceptance tests for industrial type boilers and steam generators has now been completely revised and extended to cover oil-fired installations. It can be used to assess the level of performance at a later date.

# Plant Protection with Epoxide Resin Paints

By D. A. Shingleton,\* B.Sc., Ph.D.

*The suitability of epoxide resin surface coatings for the protection of chemical plant and equipment is reviewed in this article. Mention is made of different types of cold-cured resins available and several examples are given of the application of these paints for the protection of process plant, particularly storage vessels and pipelines. Finally, recent developments in this field, including isocyanate paints and zinc-rich primers, are discussed.*

EXPOSURE to the conditions which exist in chemical plants and refineries undoubtedly represents one of the most searching tests for any surface coating. Apart from the localised highly corrosive atmospheres which can exist in the immediate vicinity of chimneys, flues and chemical plant, these installations are frequently situated in industrial areas where atmospheric pollution is considerable. Spillage of organic solvents and corrosive chemicals is another formidable factor to be contended with, and there is also a variety of different substrates, including 'difficult' alkaline ones such as concrete, which require protection. All these factors demand a very versatile surface coating which must have an extremely high degree of chemical resistance combined with excellent adhesion and physical properties. Moreover, it is essential that long-term protection is afforded, since periods of shut-down of chemical plant for maintenance purposes can be costly.

Before the advent of air-drying paints based on epoxy resins, the adequate protection of chemical plant was very often an extremely difficult problem. Air-drying paints based on vinyl resins, chlorinated rubber and bitumen are relatively cheap and have good chemical resistance, but suffer from all the inherent disadvantages of non-chemically converting binders. For example, they have poor solvent resistance, a factor which can also make overcoating difficult and, except with bitumen, a low dry film thickness is obtained with one coat, owing to the low solids content of the paints. Oleoresinous and alkyd paints cross-link at ordinary temperatures by an

oxidative mechanism, but largely by reason of the ester linkages in the molecules, do not possess the chemical resistance which is required.

Epoxide resin-based paints, however, have outstanding chemical resistance accompanied by extremely good hardness, flexibility and adhesion. They are easy to apply, have good build, and although higher in cost than the paints mentioned above, nevertheless offer real economic advantages on account of the effective and long-term protection which they provide in extremely difficult conditions. Labour costs which constitute a very large proportion of the total expenses involved in surface protection are therefore much lower, since repainting is not required so frequently.

## Epoxide resins

The most widely used epoxide resins are a class of polymer made by allowing epichlorohydrin and diphenylolpropane to react in various proportions in an alkaline medium. The resulting pale amber-coloured resins may be represented by the general Formula A.

As typified by the *Epikote* resins, the value of  $n$  in the general formula may range from 0 up to approximately 12. The lower molecular weight resins are viscous liquids, whilst those of higher molecular weight are solids with melting points up to 150°C.

The resins have few uses in the unreacted or 'uncured' state, and require to be crosslinked with certain chemical reagents, known as 'curing agents', before they can be used as the basis of a surface coating.

One of the two basic methods by which epoxide resins may be cured

at ordinary temperatures to produce a paint film is by the reaction between active amino hydrogen atoms of polyamines and related compounds, and the terminal epoxide groups of the resin molecules. This may be represented by formula B.

Since this reaction is generally spontaneous at ordinary temperatures, paints of this type are two-can systems with limited pot-life (*i.e.* usable life), and it is necessary to mix both components before use.

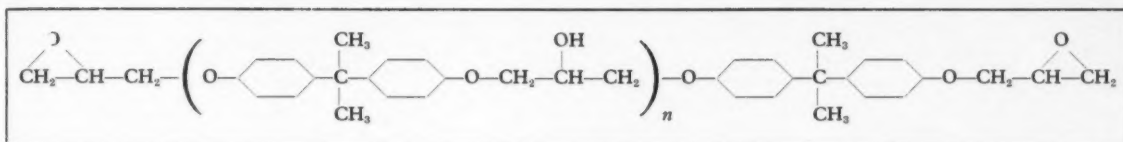
Over the past decade, several different types of these 'cold-cured' epoxide resin paints have been developed, all of which are characterised by this mode of crosslinking.

## (a) Amine-cured epoxide resin paints

For cure with amino compounds, the preferred grade of epoxide resin for best all-round properties is a solid one with an average molecular weight of around 900, and since the curing agents usually exhibit a functionality of four or five in their reaction with epoxide groups, the resulting cross-linked network possesses great toughness. It is nevertheless extremely flexible, for the length of the epoxide resin molecule is such that the crosslinks are at a sufficient distance apart to permit a considerable degree of molecular freedom between them. The excellent adhesion may be attributed to the polar nature of the macromolecule. Furthermore, the very stable carbon-carbon, carbon-nitrogen and ether linkages, which constitute the skeleton of the network, account for the high chemical resistance.

\*Shell Chemical Co. Ltd.





Formula A



Formula B

The simple aliphatic polyamines themselves, such as ethylene diamine and diethylene triamine, are now less frequently used as curing agents. The proportions required are critical and inconveniently small (about 6% by weight), and unless the mixed components are allowed to 'age' for 12 to 16 hr. before use, the films can develop a surface bloom when applied in certain cold, humid conditions. The volatility of the amines can also result in their loss by evaporation and they require care in handling.

However, adducts of epoxide resins with excess of these polyamines suffer from none of the above limitations. They are themselves resinous polyamines and can either be employed as prepared in solution ('*in situ*' adducts) or isolated as solids ('isolated' adducts). The systems have a pot-life of at least 24 hr. after mixing and the films dry in air at ordinary temperatures within a few hours, although up to seven days is required before they develop their full chemical resistance.

The chemical and solvent resistance of these systems is the best of all the cold-cured epoxide resin paints and is of an extremely high order. They

also possess outstanding exterior durability in highly corrosive atmospheres.

#### (b) Polyamide-cured epoxide resin paints

The polyamide resin curing agents are essentially another modification of the simple polyamines. They are usually condensation products of thermally dimerised fatty acids with polyamines such as ethylene diamine and they still possess some amino groups derived from the latter; these are then available for reaction with the epoxide groups of the epoxide resin. A solid epoxide resin with an average molecular weight of about 900 is again the preferred grade and usually constitutes 50 to 75% of the total resin present. The higher the proportion of epoxide resin used, the higher is the chemical resistance and hardness. Increasing the proportion of polyamide resin results in greater film flexibility.

The cured films are in most respects similar to those of the amine-cured epoxide resin paints. However, they have even greater flexibility which is believed to be attributable to the wider spacing of the reactive amino groups along the polymer chain. Their

water resistance is better and there is less tendency to 'bloom', but the films are softer and the chemical and solvent resistance, although still of a high order, is not so great as that of the amine-cured compositions. The rate of cure of the polyamide systems is slower with a longer pot-life.

#### (c) 'High-solids' epoxide resin paints

It is now widely recognised that, for effective and lasting protection, a minimum paint film thickness of 5 mils (0.005 in.) is necessary, and with solvent-borne paints this means the application of some three to five coats. However, the development in recent years of low-viscosity polyamides and related products has made possible the formulation of two-can 'high-solids' epoxide resin paints which may be applied by brushing to give films of 5 to 8 mils thickness in one coat. Only one coat is therefore required to produce the same film thickness as four to five coats of a solvent-borne paint, which represents a great saving in the time, labour and hence costs of application. Furthermore, the virtual absence of an evaporating solvent reduces fire hazards and minimises the need for ventilation when the paint is applied in a confined space. The low-viscosity liquid grades of epoxide resin are employed, and the mechanism of cure is essentially the same as for the amine-cured systems already de-

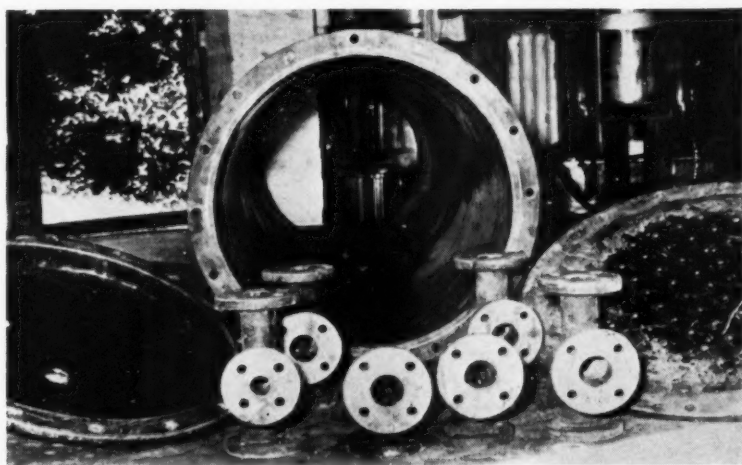


Fig. 1. Two views of an Indian water demineralising plant coated with 'Epikote' solventless varnish

scribed and is, of course, independent of the presence of atmospheric oxygen. Furthermore, 'through hardening' of the films is not complicated by solvent release difficulties and these are the two main reasons which make the application of such thick films feasible.

These paints have a short pot-life of about 1 hr. and their high viscosity means that they must be applied by brushing, although recently airless spray equipment has been successfully used. Very low-viscosity latent curing agents such as *Epikure H1* and *Epikure H2*, which require the agency of atmospheric moisture to catalyse the reaction with epoxide resins, are a more recent advance. These allow the formulation of 'high-solids' systems, with a pot-life of 6 to 8 hr., which can be applied using conventional spraying equipment without the danger of the spray gun being fouled by polymerised material.

'High-solids' epoxide resin paints exhibit the extremely high chemical resistance characteristic of amine-cured systems. They are used where the long-term protection associated with high build is required and where frequent cleaning or abrasion demands a thick durable coating.

#### (d) Epoxide resin/coal-tar paints

Paints based on coal-tar pitch alone are well known and are characterised by excellent water resistance and cheapness. However, their defects include rather poor adhesion, relatively low softening points and low resistance to organic solvents. Certain coal-tar pitches can be blended with epoxide resins and the mixture can be cured with the amines, amine adducts or polyamides previously described. Liquid epoxide resins and solutions of the solid grades may be employed, and it is possible to obtain high build with only one coat, films 3 to 4 mils thick being quite normal. The amines and amine adducts give films with good physical properties which will resist long-term immersion in distilled water, dilute alkalis and aliphatic hydrocarbons but not mineral acids or aromatic hydrocarbons. The polyamide curing agents give better flow and more flexible films, but these systems are softer and have lower solvent resistance.

Epoxide resin/coal-tar paints can be applied by spraying or brushing and dark-coloured and aluminium finishes can be formulated.

#### Epoxide resin esters

The other basic method by which epoxide resins may be cured at

ordinary temperatures to give a paint film is by polymerisation of their fatty acid esters. It can be seen from their formula that the epoxide resins are polyols and thus they can be reacted with unsaturated fatty acid derived from naturally occurring drying oils. Both the epoxide and hydroxyl groups are esterified. The solid epoxide resin with an average molecular weight of about 1,400 is normally employed, and the epoxide resin esters which are produced can crosslink by polymerisation of the fatty acid residues in an analogous manner to the corresponding oil-modified alkyds. Paints based on these modified epoxide resins thus have the advantage of being one-can systems. They have excellent exterior durability, although the oil content limits their chemical and solvent resistance. However, the epoxide constituent makes these paints more resistant than alkyds to mildly polluted atmospheres and dilute chemicals. The films are harder, and since they tend to 'chalk', they pick up less dirt than alkyd- or oil-based paints.

#### External protection of installations

For the protection of process plant, structural steelwork, linework and buildings, the type of paint selected depends on the environmental conditions and economic considerations.

Paints based on linseed and soya epoxide resin esters are the most widely used of the epoxide resin systems, since they provide excellent long-term protection in mildly corrosive or salt-laden coastal atmospheres where alkyds and other conventional paints break down relatively quickly. They make excellent primers and may

also be applied over conventional red-lead-based primers if necessary. Finishes pigmented with aluminium have the usual good weathering properties associated with this pigment, and show less tendency to tarnish and pick up dirt than normal oil-based aluminium paints. However, pigmented finishes in white, grey, blue and other pastel shades are now increasingly used. These show 'chalking' after 9 to 18 months, thus maintaining a clean, bright surface, the degree of chalking being insufficient to cause film deterioration. Fig. 1 shows a water demineralising plant coated with *Epikote* solventless varnish.

Wherever spillage of solvents and corrosive chemicals is likely to occur, however, or in highly polluted atmospheres such as exist in the neighbourhood of acid and alkali plant and flues and chimneys carrying corrosive fumes, the high chemical resistance of the amine-cured epoxide resin paints is required. These paints are now frequently employed where no other paint has been found which will resist the severe conditions experienced. Careful surface preparation and adequate film thickness (5 to 7 mils) are, of course, essential to achieve this protection, but there is no need for rust-inhibitive pigments such as red lead. This pigment in fact can have a deleterious effect in the presence of hydrogen sulphide. The 'high-solids' epoxide resin paints can provide a real economy in painting operations here. Where appearance is not so important, the relatively cheap coal-tar epoxide paints are suitable, for they usually have adequate chemical resistance, give good build in one coat and have excellent weathering properties.

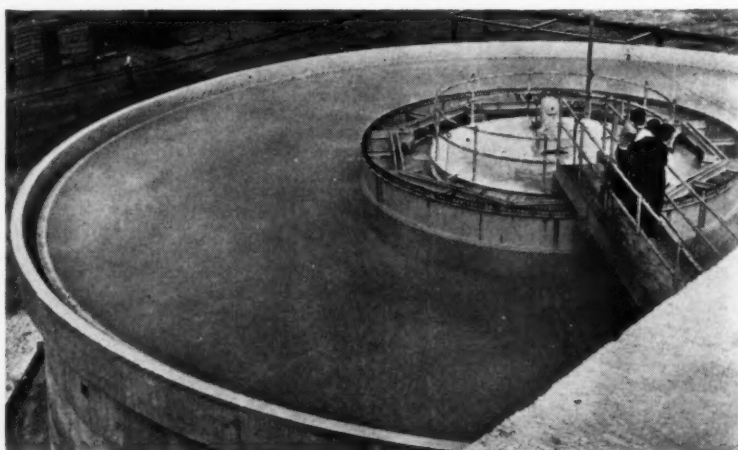


Fig. 2. The concrete tank and steel stirrer of this brine circulator have been painted with 'Epikote' resin-based paint

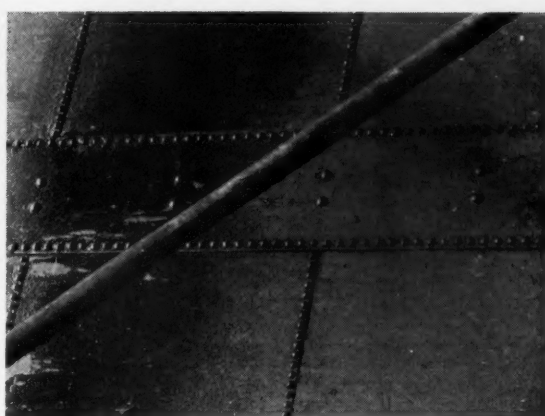


Fig. 3. On the left hand, the effect of solvene on a conventional paint six months after application in the water seal of a gasholder. On the right, the same section of the gasholder two years after painting with 'Epikote' resin ester-based system

### Concrete protection

Materials such as concrete, asbestocement, brickwork and plasterwork are alkaline and are chemically attacked in various degrees, particularly by acids and acidic vapours. Moreover, they are generally unattractive and not very easy to clean when contaminated. Oil-based paints are rapidly saponified when applied to concrete and, although vinyls and chlorinated rubber paints have the good alkali resistance required and are impermeable to water, they often show unsatisfactory adhesion in addition to their disadvantages mentioned earlier.

The amine-cured epoxide resin paints are widely used here. They effectively seal the concrete with a strongly adhering film which prevents efflorescence and resists the alkaline salts extracted from the concrete by moisture. With their high impact and abrasion resistance, the coatings will withstand quite heavy vehicular and pedestrian traffic and so are particularly effective on the floors surrounding reaction vessels where spillage also occurs and frequent cleaning is necessary. The high-solids systems have the further advantage that a smooth coating over these rough substrates can usually be obtained with only one coat.

### Tank linings

The inertness of cured films of the amine-cured epoxide resin paints towards a very wide range of solvents and chemicals has led to their widespread use for lining metal and concrete storage tanks, which in many cases would otherwise suffer severe corrosion. In fact, epoxide resin linings are frequently the only practical solution to the handling problems associated with some of these com-

pounds, for to construct the tanks of more resistant materials such as stainless steel is usually impracticable. A further reason for lining a tank is to prevent contamination of the contents by fine rust which can occur even though the amount of corrosion is small.

Caustic soda, liquid ammonia, fatty acids, aliphatic and aromatic hydrocarbons, acetone, isopropyl alcohol, trichlorethylene and refined petroleum gasolines and fuels are some of the wide range of substances which can be stored or transported in epoxide resin-lined tanks. In addition, the toughness and abrasion resistance of these films makes them highly suitable for lining vessels which contain solids and powders.

The linings are usually titanium dioxide-pigmented amine-cured epoxide resin paints, five to six coats being applied over a shot-blasted and carefully cleaned substrate.

The 'high-solids' systems are becoming increasingly popular and, in many cases for liquids such as water, the cheaper coal-tar/epoxide resin paints are perfectly adequate. Fig. 2 shows a brine circulator coated with epoxide paint. Fig. 3 shows the effect of solvene in the water seal of a gasholder on a conventional paint six months after use, and on the right the same section after two years' service after painting with three coats of *Epikote* resin ester-based system.

### Pipeline protection

Where pipes are above ground, the most suitable protective paints for various conditions have already been discussed. However, pipelines are often buried and, in aggressive clays for example, the corrosion rates of

bare steel piping can be as much as 50 to 100 mils p.a. Cathodic protection, hot applied coal-tar enamels and asphalt coatings and plastic tapes are all employed to combat this corrosion, but the use of thermosetting coal-tar/epoxide resin paints does offer a number of important advantages. Thus, when hot liquids are carried, these coatings have no tendency to flow. Their excellent hardness and adhesion lessens the possibility of mechanical damage during transport and laying, and since they are unaffected by short periods at 400 to 500°F., pipes can be pre-coated to within a few inches of the end of each section so that only a small area of each pipe need be painted on the site after jointing. Compared with the other coatings, application is very easy, and the recommended 20-mil-thick coating can be applied in one or two coats using the correct spraying technique, or flow-coated onto the preheated pipe.

As in the case of tank linings, internal pipe linings prevent corrosion and product contamination. In pipes, however, a smooth, friction-free coating also ensures maximum throughput of liquid. The 'high-solids' and amine-cured epoxide resin paints are used for this purpose not only on account of their high chemical resistance but also because their physical properties enable them to withstand the constant erosive action of the flowing liquids. It is interesting to note that long stretches of underground pipe have been cleaned and internally coated with these paints *in situ* by forcing liquid cleaners and then the epoxy paint through the pipe between two plugs. This is achieved by maintaining a carefully controlled



differential in the pressures applied at each end of the pipe.

#### Recent developments

Rapid-curing air-drying isocyanate paints based on epoxide resins have recently been developed which possess many of the desirable characteristics of both conventional isocyanate paints and the amine-cured epoxide resin systems. They are two-can paints, one component being a highly functional polyol obtained by pre-reacting a solid grade of epoxide resin with excess of a dialkanolamine. In this reaction, each epoxide group of the resin is replaced by three further hydroxyl groups and the resulting resinous polyol is therefore extremely reactive towards the polyisocyanate curing agents employed.

Although pot-lives of up to 8 hr. can be achieved, cure is rapid at ordinary temperatures and films dry hard within 2 hr. They have the excellent physical properties characteristic of the amine-cured epoxide resin paints, and in a sense the two types of system may be considered complementary to one another in chemical resistance, for the epoxide resin/isocyanate paints have outstanding water resistance and better acid resistance than the amine-cured type.

They will also cure satisfactorily at temperatures as low as 5°C., which is an important advantage when painting in winter conditions is necessary.

Such paints are eminently suitable for many of the applications in chemical plant protection already described. It has also been found that the films are exceptionally easy to free from radioactive contamination. In the protection of atomic installations, or process plant where radioactive material is being handled, this is an important advantage over most other types of paint.

The interval between the erection of chemical plant and its protection by painting can often be lengthy so that, when painting is finally carried out, the surface preparation required can be costly and is often inadequate. The recent development of an epoxide resin-based zinc-rich primer has made possible the prior shot-blasting and coating of the steelwork with the primer, before the metal reaches the site and becomes exposed to atmospheric conditions. The technique of shop-coating shot-blasted steel with a zinc-rich primer in this manner is now gaining acceptance in the shipbuilding industry.

Zinc-rich primers consisting of about 93% by weight of zinc dust and

7% of a polyamide-cured type of epoxide resin binder provide an excellent rust-inhibitive coating which can be satisfactorily overcoated with any type of paint after many months of weathering. They have extremely good adhesion to steel and are resistant to mechanical damage in handling. Moreover, the weld quality of the steel is not affected by welding over the primer and the scorching of the primer along the welding seams is negligible.

#### Conclusion

Epoxide resins have made possible the development of a range of air-drying paints whose durability and chemical resistance is of the same order as that of the best stoving paints. They are eminently suitable for the protection of chemical plant where their outstanding qualities have been thoroughly tried and tested, and today they are marketed by almost every leading paint manufacturer. Compared with conventional paints, considerable economic advantages accrue from the longer-term protection they afford in corrosive environments.

#### ACKNOWLEDGMENT

The author would like to thank the directors of Shell Chemical Co. for permission to publish this article.

## INDUSTRIAL PUBLICATIONS

**Rustproofing.** The Pyrene Co. Ltd. have issued an illustrated brochure describing their *Parkerizing* rustproofing two-stage process, applied by immersion. Their range of processes are given covering iron, manganese and zinc phosphate treatments and a table shows the range of *Parker* finishes available.

**Welded tube.** The manufacture, types and applications of *Pembrite* welded stainless-steel tubes form the subject of an illustrated booklet published by Rollo-Hardy & Co. Ltd. Methods of testing the welded tube are described and applications are suggested. Tables of the alloy composition, together with maximum pressures and weights/ft. for a range of outside diameters and wall thicknesses are also given.

**Welding.** John Booth & Sons (Bolton) Ltd. have published an illustrated booklet describing their welded steel tanks, pressure vessels and other products.

**Silicones.** 'Silicones in Engineering', coded A11, is the title of a recently published illustrated booklet by Midland Silicones Ltd. One of a special series addressed to particular industries, it shows how silicones are being used in many branches of engineering, and gives examples of their successful application. It also lists suppliers of components or equipment made with M.S. silicones.

**Multistage blowers.** Publication No. 56 on turbo multistage blowers completes the series of catalogues dealing with the *Tornado* range of blowers and exhausters for pressures varying between 1.0 and 52.0 in. static w.g., recently published by K. Blackman Ltd. The turbo multistage blowers are produced in sizes from 18 to 42 in. with a blower pressure of approximately 7½ p.s.i.

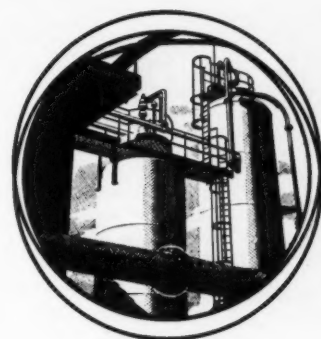
**PVC.** Tubes, fittings and valves made of PVC are comprehensively surveyed in a booklet published by Extrudex Ltd. Tables showing pres-

sure ratings are given and related to the various industrial applications of *Hi-K-80* and *Hipact*. Methods of jointing to PVC and other materials are described, accompanied by appropriate diagrams. The booklet concludes with a table showing the resistance of *Hi-K-80* to various chemicals.

**Air heaters.** An illustrated brochure entitled 'Forced Circulation Air Heaters' has been issued by the Incandescent Heat Co. Ltd. It is concerned with metallic heat exchangers for the heating of air and other gases. The types of air heater described are for use in the temperature range 500 to 1,000°C. under working pressures ranging from atmospheric to approximately 500 p.s.i.

**Caustic soda.** A new booklet available from Murgatroyd's Salt & Chemical Co. Ltd. is designed to provide information for those concerned with the buying, storing, handling and use of caustic soda, and provides a section on technical data.

# Materials of Construction for Chemical Plant



## ZINC COATINGS

By A. D. MacLennan,\* B.A.

*This article forms the twentieth in our series on 'Materials of Construction for Chemical Plant'. Previous articles in this series have included PVC, lead, nickel, stainless steels, graphite, polyolefines, copper, timber, platinum, titanium, aluminium, reinforced plastics, cast iron, mild steel, silver, glass, ceramics, new metals and rubber. In the chemical industry, zinc coatings are mainly used for protecting iron and steel plant from corrosion. They can consequently be considered as a material of construction, combining the strength of steel with the protective qualities of zinc.*

ZINC has been used by man as a constituent of brass since Greek and Roman times, long before the metal itself was isolated. Methods of smelting zinc probably originated in China or India, and in Europe commercial smelting began in the middle of the 18th century.

The major use of zinc today is as a protective coating for iron and steel, and other important uses are sheet zinc for building and zinc alloy die castings for a wide variety of engineering applications.

In chemical plant, zinc is mostly used in the battle against corrosion of iron and steel, either for one of the five generally used methods of applying a zinc coating or for cathodic protection. It is, of course, widely used in brass, but since this application has been described in the article on copper, it will not be further discussed here.

The development of modern chemical processes has generally meant that atmospheric conditions have become more corrosive. Whilst expensive new materials are sometimes used for the construction of vessels and plant, there are large quantities of ancillary steelwork which are subjected to severely corrosive conditions. Maintenance costs, with their high labour factor, are continually rising and plant engineers are today prepared to consider

more sophisticated methods of protecting steelwork, where higher initial costs are more than compensated for by reduced maintenance expenditure over the years.

### How zinc protects steel

Zinc owes its ability to protect iron and steel from corrosion to two properties: firstly, it is a chemically active metal situated at the anodic end of the galvanic series and is thus able to protect steel sacrificially under certain circumstances; secondly, its corrosion products are generally dense and adherent, which means that its rate of corrosion is usually much less than that of steel. A zinc coating thus acts primarily as a slowly corroding barrier between the steel and the atmosphere and it also has the ability to protect small imperfections or scratches in the coating sacrificially. Zinc can also protect iron and steel as a sacrificial anode in cathodic protection schemes for low- and medium-resistivity environments.

About half of the world's zinc production is used in the form of zinc coatings on iron and steel and the five principal methods of coating are galvanizing, zinc spraying, zinc plating, sherardizing and painting with zinc-rich paints. These processes will be briefly described, since they have slightly different properties, and for

any particular application one process is usually more appropriate than the others (see Table 1).

**Table 1. Typical coating weights obtained by different processes**

Method of application	Typical coating weight, oz./sq.ft.
Hot-dip galvanizing	1 to 2½
Zinc plating ..	0.1
Sherardizing ..	½ to 1
Zinc spraying ..	2
Zinc-rich paint (one coat) ..	½

### Hot-dip galvanizing

Hot galvanizing is by far the most widely used coating process and has been practised commercially for almost two centuries. The process is still fundamentally the same, but the modern plant uses up-to-date methods of control and applies the results of scientific research carried out in many parts of the world. The process is applied to fabricated articles (general galvanizing) and also to semi-fabricated materials such as sheet, strip, wire and tube.

Basically the process consists of dipping thoroughly cleaned iron or steel in a bath of molten zinc. Whilst the material is in the galvanizing bath, layers of zinc-iron alloys are formed

\*Zinc Development Association.

and, on withdrawal, a layer of pure zinc is retained on the surface of the alloys. Before immersion, all scale and rust must be removed and this is normally achieved by pickling in dilute acid; for castings, shot-blasting is generally used.

For certain grades of strip intended for severe fabricating operations, the formation of the rather more brittle alloy layers is suppressed by making additions to the galvanizing bath.

The thickness of the coating will generally depend on the nature of the article which is being dipped and on its surface roughness, the weight of coating varying from about 1½ oz./sq.ft. on fabricated sheet steel to over 3 oz./sq.ft. on heavy structural sections. As the article is completely immersed in the zinc, all parts of it receive an adequate coating and all edges, rivets, seams and welds are covered.

Galvanizing is usually the most economical method of obtaining a relatively heavy coating of zinc, though the size of article which can be dipped in one piece is limited by the sizes of bath available. The latter difficulty can often be overcome by using a bolted construction or by welding galvanized sub-assemblies and subsequently protecting the weld areas by zinc spraying or painting with zinc-rich paints. Heating welded fabrications in a galvanizing bath to 450°C. can sometimes cause distortion, but this can often be avoided by modifying welding techniques so that the stresses are balanced.

Since galvanizing is a relatively old process it is natural that in some of the traditional applications newer materials such as plastics have provided severe competition. However, new applications are also being found for galvanized steel, and the tonnage of zinc used for galvanizing is still rising. At the present time, approximately 6% of the country's output of iron and steel is hot-dip galvanized.

### Zinc spraying

Zinc spraying involves projecting 'atomised' particles of molten zinc onto a surface which is generally prepared by shot- or grit-blasting. The process was developed at the beginning of this century and has rapidly expanded to become an important method of applying a zinc coating. There are three basic types of pistol in commercial use employing powder, wire and molten metal.

A zinc-sprayed coating is slightly rough and porous and provides a good mechanical key for paints. Zinc

spraying has the advantage over galvanizing that it can be applied on site to work of almost any shape or size. It is also possible to apply the coating to the thickness desired, and coatings of 5 to 6 oz./sq.ft. have been applied in special cases. On the other hand, uniform coverage is dependent on the skill of the operator except on automatic installations handling long runs of similar materials. Zinc spraying is not normally suitable for coating the insides of cavities, etc., though special nozzles are available for coating the insides of short lengths of tube. New pistols have recently been developed with higher rates of throughput which have helped to reduce costs. The process is seldom economical for treating 'open' structures such as wire mesh because of the heavy wastage which results.

### Zinc plating

Zinc coatings may also be applied to iron and steel surfaces by electroplating, and this process is sometimes called electrogalvanizing. Most zinc plating baths contain either acid sulphate solutions or alkaline cyanide solutions.

The cyanide baths have the greater throwing power, which makes them more suitable for complex shapes; on the other hand, sulphate baths have a more rapid rate of deposition and are more suitable for plating sheet, etc.

A normal zinc-plated coating has a dull matt appearance, but bright lustrous deposits can be obtained from cyanide baths using brighteners. Modified acid baths are used for the

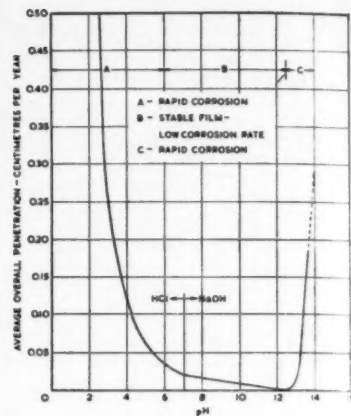


Fig. 2. Variation of corrosion resistance of zinc with acidity

continuous electrogalvanizing of strip and wire.

A zinc-plated coating is ductile and consists of pure zinc which adheres by metal-to-metal bonds. The process is particularly suitable for coating delicate articles, and when a fine smooth finish is essential; it is not normally suitable for applying heavy zinc coatings and average coatings range from 1/10 to 1/2 oz./sq.ft.

### Sherardizing

Sherardizing is a cementation process in which the article to be coated is heated in a revolving drum containing zinc dust to a temperature slightly below the melting point of zinc. Diffusion takes place and the resultant coating consists entirely of zinc-iron alloys. It has a matt grey appearance and is of very uniform thickness, closely following the contours of the basis material. It is thus particularly suitable for small complex articles, and sherardized nuts and bolts mate freely after coating provided that tolerances have been allowed for the thickness of coating. Because the coatings consist of zinc-iron alloys, they are harder than those obtained by other methods and have good resistance to abrasion. The volume of drum which can be used is limited by the need to maintain uniform conditions throughout. The usual drums have a 2-ft. square cross-section and are 6-ft. long, but narrow drums up to about 20 ft. in length are available for treating items such as tubes. The usual weight of coating is between 1/2 and 1 oz./sq.ft. but heavier coatings can be applied.

### Painting with zinc-rich paints

In recent years special paints have been developed which will deposit

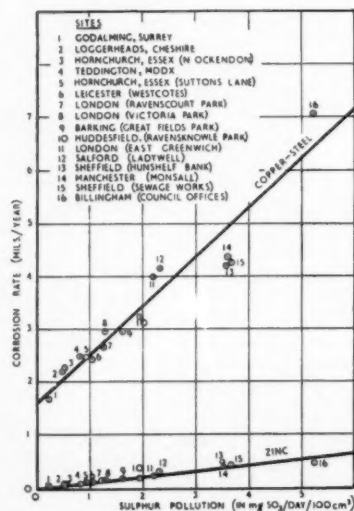


Fig. 1. The Hudson and Stanners exposure tests on specimens of zinc and copper-steel



thin films of metallic zinc possessing many of the properties common to other zinc coatings. These paints contain 92 to 95% metallic zinc in the dry film and are capable of protecting the underlying steel sacrificially. They are normally of the air-drying type but stoving primers are also available. Special binders are required and plasticised polystyrene, chlorinated and isomerised rubber, etc., are generally used for this purpose. Zinc-rich paints based on silicate binders have recently been developed and are reported to give a very good performance.

As with all types of protective system, the best results are obtained when the surface has been thoroughly cleaned before coating, but the paints do perform surprisingly well when applied over a thin film of adherent rust. An advantage of zinc-dust paints is that they can be easily applied without the use of costly equipment and skilled labour. The abrasion resistance is not so good as that of other zinc coatings but better than that of other paints. They are useful for touching up areas of other zinc coatings which have been damaged in some way. A single coat of zinc-rich paint will give a zinc coating of about 0.4 oz./sq.ft.

### Corrosion resistance

In the last 20 years the corrosion resistance of metallic and paint coatings has been evaluated by exposure

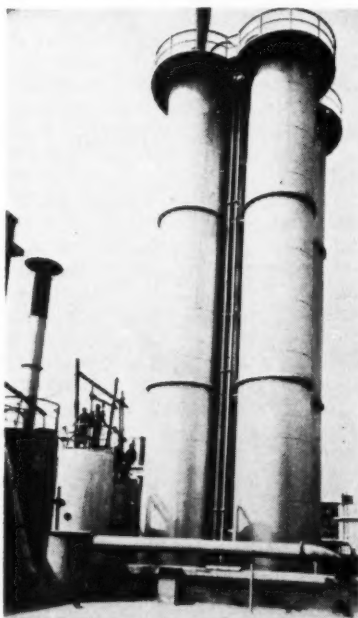


Fig. 3. Part of an oil refinery at Alexandria painted with zinc-rich paints

Site	Type of atmosphere	Exposure for 5 yr.		Estimated life of 2 oz./sq.ft. zinc coating*	
		Corrosion rate, mils/yr.			
		Ingot iron	Zinc		
Llanwrtyd Wells	Rural	2.2	0.09	24	34
Calshot, Hants	Marine	4.5	0.13	34	23
Motherwell, Scotland	Industrial	2.4	0.18	13	17
Woolwich, Kent	Industrial	2.7	0.16	17	19
Sheffield (University)	Industrial	3.4	0.20	17	15
Sheffield (Attercliffe)	Industrial	4.7	0.60	8	5
Dove Holes Tunnel	Railway tunnel (steam)	2.5	2.9	0.8	1
Khartoum, Sudan	Dry, tropical	0.0	0.01	—	300
Abisko, N. Sweden	Sub-polar	0.1	0.01	10	300
Aro, Nigeria	Inland, tropical	0.3	0.02	15	160
Basrah, Iraq	Dry, sub-tropical	0.3	0.01	30	300
Singapore	Marine, tropical	0.4	0.03	13	100
Apapa, Nigeria	Marine, tropical	0.8	0.03	27	100
Congella, Durban	Marine, industrial	3.0	0.18	17	17

\* These lives have been calculated on the assumption that 10% of the original zinc remains when rusting of the basis steel begins, which Gilbert found to be true for coatings of reasonable uniformity.

tests in many different environments conducted by independent bodies such as B.I.S.R.A. and A.S.T.M.<sup>1-3</sup> These tests have shown that, in any particular environment, the life of a zinc coating is independent of its method of application and is proportional to the weight of zinc deposited on a unit surface area. As a result of these tests, the likely performance in a particular atmospheric environment can now be predicted within reasonable limits, and the results reported by Hudson and Stanners are summarised in Table 2.

It has also been shown that the alloy layers in hot galvanized and sherardized coatings corrode at a similar rate to pure zinc, although there is some evidence that in industrial atmospheres they corrode more slowly than pure zinc.

### Effect of sulphur pollution

It has been pointed out earlier that the slow corrosion rate of zinc arises from its ability to form a tightly adherent layer of corrosion products. If these corrosion products contain a soluble zinc salt and the article is exposed to rain-water, the rate of corrosion will naturally be increased. Zinc sulphate is very soluble and this accounts for the fact that the rate of corrosion of zinc in an industrial atmosphere can be four to five times greater than in a rural or marine environment. Hudson and Stanners conducted a series of exposure tests on specimens of zinc and of a steel containing 0.2 to 0.3% copper at 16 sites in the United Kingdom and the sulphur pollution of the atmosphere was also measured.<sup>2</sup> Their results are shown graphically in Fig. 1.

### Corrosion in other media

When in contact with liquids, the degree of acidity or alkalinity is an important factor in determining the corrosion resistance of zinc. The accompanying graph (Fig. 2) shows that the protective film forms between pH values of 6 and 12.5. Zinc coatings can thus withstand all but the strongest alkalis, but they are not recommended in contact with solutions which are acidic.

Zinc in trace quantities is a necessity of the human body; in quantities greater than this it can produce sickness though it is in no sense dangerous. Zinc coatings should not, therefore, be used in contact with liquid foods that are at all likely to become acidic. The small quantities which are picked up from galvanized water pipes are not harmful and zinc coatings can safely be used in contact with dry foodstuffs.

The corrosion of zinc in fresh water will again depend on its ability to form a protective layer. Thus distilled water and soft water containing high quantities of dissolved oxygen and carbon dioxide corrode zinc coatings more rapidly than the harder waters which tend to deposit a hard surface scale. This may not, however, be the whole story, for some waters (particularly those from chalk boreholes) can dissolve small quantities of copper. If, therefore, such water is fed through copper piping and then allowed to come in contact with a zinc coating, small quantities of copper will plate out on the surface of the zinc leading to local corrosion cells and rapid local attack.

The behaviour of zinc coatings which are buried also varies consider-

ably. Good performance will be obtained in most soils except those which are acidic or anaerobic in character. Wet cement has a slight etching effect on zinc, but this ceases when the cement has dried.

If a fresh zinc surface is allowed to stand with droplets of condensation on it, the hydroxides and carbonates, which normally form the tightly adherent film, may appear as a bulky white precipitate sometimes known as white rust. This condition can arise in storage and transport when fluctuations in temperature are combined with poor ventilation. Whilst a chromate passivation treatment on the zinc surface will help to avoid this trouble, dry, well-ventilated storage conditions are the only sure preventive.

### Painting zinc coatings

For many applications a zinc coating will give satisfactory protection without additional treatment, but in aggressive atmospheres such as are generally found in chemical plant or for aesthetic reasons, it may be necessary to paint over the zinc coating. It may be asked why, if one is going to paint anyway, is it an advantage to first coat the material with zinc. There are several reasons why this is sound policy.<sup>4</sup>

(a) The life of the paint coating is extended; in fact, it has been shown that the life of a zinc + paint system

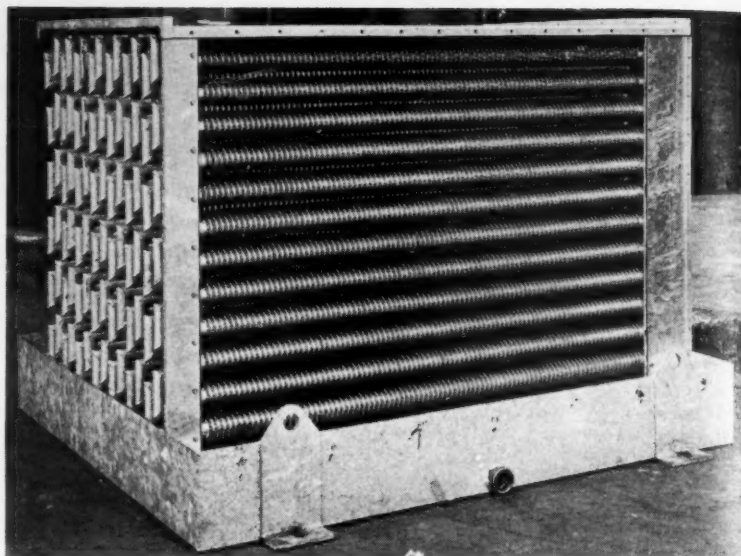


Fig. 5. Galvanized tube batteries for cargo refrigeration

is considerably longer than the sum of the average lives of each coating by itself.

(b) The resistance to mechanical damage is greatly improved and, even if the paint coating is removed in some places, the steelwork is still protected by the zinc coating.

(c) The formation of rust is prevented; more important, there is no rust creep under the paint film. This means that the task of surface preparation for maintenance is considerably simplified and is more likely to be effectively carried out.

(d) Parts of a structure which are inaccessible for maintenance painting will be more adequately protected.

Published data show that over a period of 25 years, depending on the environment, savings of 25 to 50% can be made on total maintenance costs by using a zinc coating under a paint system.

Paint systems for zinc coatings must be chosen with some discretion. Freshly hot galvanized coatings are relatively smooth, but calcium plumbate primers will adhere satisfactorily to these surfaces, or wash primers can be used. After a weathering period of six months, most conventional paints will adhere well to galvanized steel.

Zinc-sprayed coatings present rather a different problem, since the porous surface, whilst providing a good mechanical key, can draw off some of the binder and heavily pigmented primers should, therefore, be avoided. The painting of sprayed metal coatings is under consideration at the present time, but the current advice of experts,

based on good results which have been achieved, is that the structure should be painted as soon as possible after metal spraying with one or two coats of a suitable priming paint.

### Applications

Some applications where zinc coatings have been used will now be briefly discussed. In each case the performance of the particular zinc coating which was chosen is a guide to the performance of other zinc coatings in a similar environment.

Zinc-coated tanks and cylinders are widely used in oil refineries and chemical plant for storing oil and petroleum products, town gas, chlorine, carbon dioxide and other industrial gases as well as a wide range of chemicals and water. Fig. 3 shows part of a refinery at Alexandria painted with zinc-rich paint. Fig. 4 shows the galvanized steelwork at a polyethylene plant.

Refrigerating and cooling equipment as well as degreasing plants are almost universally protected by a zinc coating. Fig. 5 shows gilled tube batteries for cargo refrigerators. Fig. 6 shows a

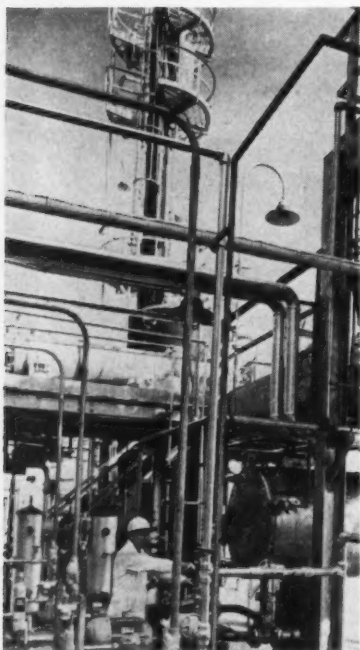


Fig. 4. Galvanized steelwork at the Celanese polyethylene plant, Houston, Texas

The material of construction for chemical plant which will be discussed in next month's issue of **CHEMICAL & PROCESS ENGINEERING** will be

**CEMENT**

Table 3

Property	Theoretical	Actual*
Current efficiency, %	—	95
Electrochemical equivalents: amp.-hr./lb.	372	353
amp.-hr./cu.in.	96	91
lb./amp.-yr.	23.5	24.8
cu.in./amp.-yr.	91	96
Weight/volume data: specific gravity	7.14	
lb./cu.in.	0.26	
cu.in./lb.	3.88	
Solution potential: v. Ag/AgCl, V		-1.05
v. Cu/CuSO <sub>4</sub> , V		-1.10
Driving potential to cathodic polarised to -0.80 V (v. Ag/AgCl), V		0.25

\* Typical data in sea-water.

galvanized ring gas main. Other applications include germinating drums in breweries and liquid oxygen evaporators. Process tanks for the production of rayon yarn are protected by zinc coatings and here the zinc has the additional advantage of preventing discoloration of the product.

Zinc coatings are being increasingly used on structural steelwork of all types to reduce maintenance costs. In a paper presented at a symposium on the protection of structural steel, F. R. Himsworth discusses the reasons why metallic coatings show advantages for protecting steelwork in chemical plant.<sup>5</sup> Reasons for preferring sprayed zinc coatings to sprayed aluminium coatings are given. The economic aspects are also discussed.

In a report published by the Gas Council, L. A. Ravalld describes the use of metallic coatings for protecting steel in gasworks.<sup>6</sup> Both galvanized and zinc-sprayed steel have given valuable service in a number of applications and some figures on costs are also given.

Extensive use is made of galvanized steel by the chemical companies on the Gulf Coast of Texas where the severity of the industrial atmosphere is accentuated by marine spray from the Gulf. J. W. Sicard describes the construction of the multimillion-dollar Fortiflex plant for the Celanese Corp. of America in 1956:<sup>7</sup> galvanized steel was used in all exposed outdoor areas, based on experience at its petrochemical plant near Bishop, Texas. Another chemical company on the Gulf Coast, who are currently using 6,000 to 10,000 tons of galvanized steel annually, have installed their own plant to deal with this large tonnage.

#### Zinc anodes for cathodic protection

Cathodic protection applications for zinc anodes in chemical plant are mainly concerned with the protection of steel foundations, underground

pipework and the interior wetted areas of storage tanks, heat exchangers and some large-diameter pipelines. In addition, it is now realised that the presence of copper earthing rods can cause severe attack on adjacent steelwork, and these installations are being increasingly replaced by back-filled zinc anodes.

Sacrificial zinc anodes have been in commercial use since 1824 when Sir Humphrey Davy demonstrated their effectiveness for protecting the copper sheathing on the hulls of ships. Until 1954, their performance was erratic due to the formation of tightly adherent oxide films which reduced or prevented the flow of current. Independent work in the United States, Canada and Great Britain showed that the presence of iron in excess of 14 p.p.m. was the cause of the trouble and that this was the only important impurity. Subsequent work has shown that permanently active anodes can also be produced by alloying zinc with 0.5 to 1.0% aluminium and 0.25 to 0.5% silicon or cadmium to counteract the presence of iron.

The high-purity and zinc alloy anodes do not polarise with time and,

as they have a negligible self-corrosion rate, their efficiency at all current densities is very high. Another important feature of these anodes is their self-regulating characteristics, which means that in low-resistance circuits the current output is adjusted over a wide range of response to the varying demands of the cathode surface. With a driving potential of only 0.25 V to a polarised cathode, zinc anodes do not cause the excessive evolution of hydrogen which raises the pH of the solution and results in the failure of surface coatings. The properties of zinc anodes are summarised in Table 3.

#### Conclusion

The choice of protective schemes for chemical plant will depend on a number of factors, but the economic aspects will generally predominate. Whilst the costs of maintenance continue to rise and whilst the shut-down of expensive plant to install replacements also becomes more significant, it seems clear that zinc coatings will continue to play an increasingly important role wherever iron or steel are used. Zinc-coated steel can be considered as a material of construction combining the strength of steel with the protective qualities of zinc.

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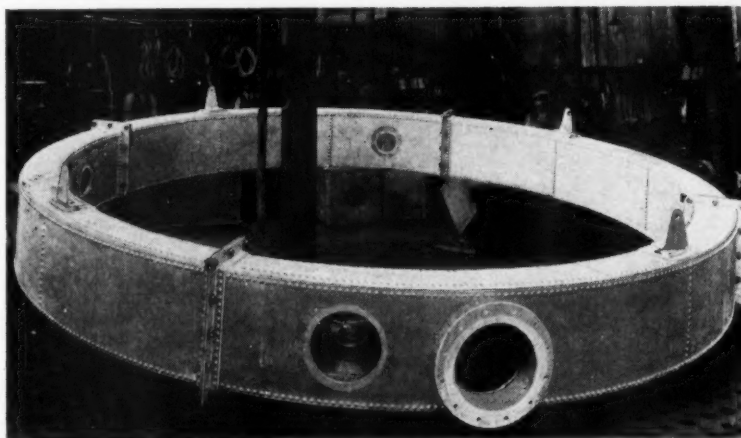


Fig. 6. Galvanized ring gas main





Fig. 1. Night view showing part of Du Pont's neoprene plant at Maydown, Londonderry

## Northern Ireland's Chemical Industry

By I. L. Hepner, Ph.D., A.M.I.Chem.E.

*A recent tour of Northern Ireland's chemical industry has shown that a tremendous chemical expansion has occurred in Ulster during the last decade. Amongst many new process plants in operation or at present under construction, there is a preponderance of synthetic fibre plants, which may in time pave the way for a synthetic textile industry following the tradition of linen.*

NORTHERN IRELAND, separated by only 30 miles of channel from Great Britain, is an integral part of the United Kingdom. Its small population of 1.4 million is largely engaged in agriculture; thus it produces about 8% of the gross farming output of the U.K., although in size it comprises only 2½% of the U.K. Nevertheless, there is a considerable industrial tradition in Northern Ireland, dating back to the thriving pre-war linen industry and busy Belfast shipyards. Shipbuilding, unfortunately, is in the throes of an acute crisis all over the U.K., and the linen industry, which was flourishing particularly during the last war, has been severely curtailed by the encroachment of synthetic fibres. Linen, like silk, has now become a high-cost special-purpose fibre unable to compete successfully with the cheaper synthetic fibres. This recession in Ulster's traditional industries has consequently led to a rather high degree of unemployment—7% of the working popula-

tion, compared with only 2.5% for Great Britain. Not unnaturally, therefore, the Northern Ireland government is keenly interested in encouraging industrial firms from abroad to open manufacturing plants in Northern Ireland and to provide local employment. So far there have been three major disadvantages that have restrained Northern Ireland's industrial development. Firstly, the handicap of Ulster's physical separation from the main U.K. economy; secondly, the relatively small market which makes a high degree of efficiency difficult to achieve; and, thirdly, the lack of virtually any indigenous raw materials. However, due to improvements in transport, the first drawback is not so serious as it used to be.

The Northern Ireland Ministry of Commerce has also tackled this problem by drawing up a long-term programme of industrial development whereby preferential loans are offered to foreign companies willing to establish factories in Ulster. The Ministry,

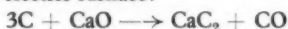
in fact, owns a large number of factory sites on which they have built standard factories. These can be rented by firms at reasonable cost and, since the war, 80 such standard factories have been leased to manufacturing companies. A major attraction for industrial development at present is undoubtedly the abundance of land for expansion. Again, unlike England, there is an ample labour force which has proved capable of adapting itself to the demands of new technical processes. Another factor of particular importance to chemical industry is the plentiful availability of fresh water (Lough Neagh is reputed to be the largest lake in Europe). As a result of these inducements, the last few years have seen a considerable burgeoning of industry in Ulster, particularly in the chemical sector.

An opportunity was recently afforded to me to study Ulster's industrial chemical development. In this way it was possible to gain a personal impression of the remarkable growth

of this particular industry and analyse its future potential. The remarkable feature about the recently established chemical plants in Ulster is, that they comprise many processes which were developed in the U.S. and recently established in Europe. For example Du Pont's neoprene plant and Chemstrand's acrylic fibre plant are the first such process plants outside the U.S. Courtauld's viscose plant is based on a continuous process and is one of the few such plants in the world.

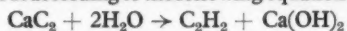
### Acetylene plant

One of the very few tonnage acetylene plants in the whole world is located at Maydown, Londonderry. Built by Carbide Industries Ltd., the plant came into production last year. The two raw materials required in the manufacture of acetylene are limestone and coke, neither of which are found in Northern Ireland. Both have to be shipped from Great Britain to the Maydown factory jetty in Loch Foyle. After unloading, the raw materials are weighed on a belt conveyor before being fed into a surge hopper. The limestone is fed into the lime kilns where it is burnt. Coke and lime are weighed in the ratio of 1 to 1.6, and dropped onto a moving belt conveyed to the top of a 100-ft.-high furnace house. Fig. 2 shows a view of the coke and limestone plant. The following reaction takes place in the electric furnace:



The electric furnace, situated on the ground floor of the furnace house, consists of a shell approximately 30 ft. diam. and 10 ft. high, mounted on wheels which enable the shell to rotate or oscillate as desired. Three electrodes are mounted in a triangular formation within the circular furnace. As each electrode is consumed in the reaction zone, fresh portions from the baked electrodes are slipped through the electrical contact clamps.

Molten carbide is tapped from the furnace and flows into tapping cars which are moved away to the cooling portion of the track. After several hours' cooling, the solidified carbide is removed from the cars, then again cooled and transported to the crushing plant and then passed to storage bunkers. From the storage bunkers the carbide is weighed and fed continuously into the Shawinigan 'dry-type' generators. The reaction of water with calcium carbide is carried out according to the following equation:



The calcium hydroxide produced in

the reactor is removed to a large bunker storage. Acetylene is conveyed by pipeline to the neighbouring Du Pont plant.

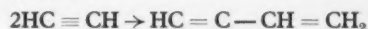
One of the main requirements of the process is an enormous amount of electrical power. Two 33,000-V cables are supplied from the nearby Koolkeragh power station, which was especially built by the Northern Ireland Electricity Supply Board for the industrial requirements of Maydown area.

### Neoprene plant

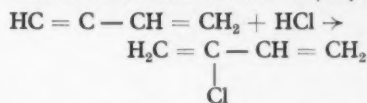
The first neoprene synthetic rubber plant outside the United States has been in operation in Maydown, Londonderry, since May 1960. The plant stands on a 365-acre site and has a total labour force of 450. The capacity of the Maydown plant is 50 million lb. p.a., considerably less than the two American neoprene plants. Most of the raw materials for this process are shipped from Great Britain. Acetylene, as mentioned above, is supplied by pipeline from Carbide Industries Ltd. adjacent to the works. Chlorine is purchased from I.C.I. at Runcorn and is transported to Maydown in a special tanker. Propane gas, brought by road from the Whitegate oil refinery in the south, is reformed to yield hydrogen. Hydrochloric acid is made on the site by burning hydrogen with chlorine. The three major operating areas in the plant are: monovinylacetylene (MVA), chlorobutadiene (CD) and polymerisation (see Fig. 1).

The acetylene gas is first purified to reduce phosphine, arsine and hydrogen

sulphide to the minimum concentration. It then passes into a reactor where it is converted, using copper catalyst, to monovinylacetylene (MVA):



The MVA is then separated from other products in a number of distillation columns and passes to the CD area where it is reacted with hydrogen chloride to form chlorobutadiene (CB):



Pure chlorobutadiene then passes to the polymerisation area where the monomer is polymerised as an aqueous emulsion to form polychloroprene (or neoprene) in the latex form. A small proportion of neoprene is required in this state by rubber manufacturers, but the bulk of neoprene is required dry. The latex is then coagulated by passing it over rotating heated rollers. Fig. 4 shows the dried coagulated film which is twisted into a rope and cut up into chips, dusted with talc and packed.

Plant waste is rigorously controlled to ensure that no toxic wastes are discharged into the river. Thus, extensive facilities to remove copper and neoprene wastes from the process streams have been provided and the total process stream is neutralised before discharging into the nearby river.

### Acrylic fibres

Since early 1959, acrylic fibres, which have a wool-like texture and are

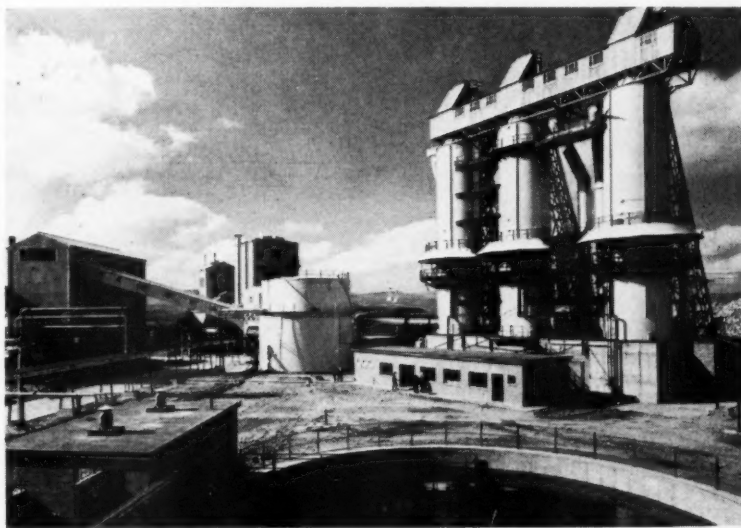


Fig. 2. Coke and limestone plant at Carbide Industries Ltd., Maydown

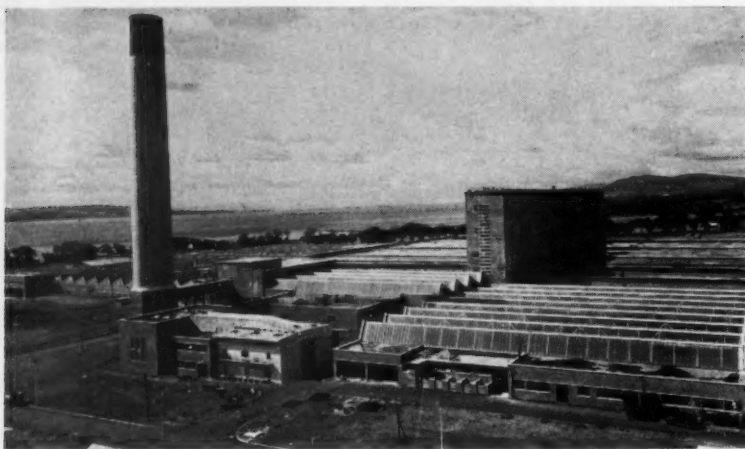


Fig. 3. Courtaulds' viscose rayon yarn plant at Carrickfergus

suitable for making into suits, knitwear, carpets, etc., have been produced by Chemstrand Ltd. in Coleraine, Londonderry. Chemstrand Ltd. is the wholly-owned subsidiary in the U.K. of the Chemstrand Corp. of Decatur, Alabama, which in turn is jointly owned by Monsanto Chemicals Co. and the American Viscose Corp. The Coleraine plant, making *Acrilan* fibre, is situated in the most scenically picturesque part of Northern Ireland. At a cost of £3½ million this is one of the most completely automated synthetic fibre plants in the world. Fig. 5 shows an aerial view of the plant.

The raw material, liquid acrylonitrile, is shipped from Billingham by chartered tanker to Coleraine harbour, where it is pumped through a specially constructed pipeline to the factory storage tanks. There the monomer is stored at reduced temperature to inhibit polymerisation. Acrylonitrile is then mixed with a co-monomer (whose function is to plasticise the polymer and facilitate its subsequent solution in the spinning bath), sulphur dioxide inhibitors and various other chemicals.

The monomer solution passes continuously into a stirred reaction vessel where polymerisation occurs instantaneously. (No catalysts are required to promote polymerisation since acrylonitrile polymerises spontaneously at atmospheric temperature.) The solution passes out of the reactor over a rotating filter drum. The solids in the solution are retained by the filter, whilst the liquid monomer and impurities pass out.

The monomer is then purified and recycled. The filter cake is washed with water, removed by scraper blades and passed over a second filter drum

where it is further washed, monomer and impurities separated and recycled. The filter cake is removed from the filter as a wet slurry containing about 70% moisture. Final drying is carried out in a very long conveyor tunnel dryer, from which the polymer emerges in the shape of small pearls.

The polymer pearls are dissolved in the organic solvent to form a spinning solution, which is once again purified by filtration and then extruded through dies into fibres. The fibres are stretched over rollers to improve strength, dried and finally crimped to give the wool-like texture.

Chemstrand recently announced that they are to increase production capacity of their Coleraine plant from £10 million to £15 million p.a.

Another synthetic fibre plant is being planned by I.C.I., who have completed the purchase of 200 acres of land at Kilroot, Co. Antrim, as a site for the *Terylene* plant. It is I.C.I.'s intention to establish *Terylene* spinning plants in Northern Ireland. It is also possible that polypropylene fibre will be manufactured at Kilroot, since I.C.I. recently acquired from Montecatini the exclusive rights for the production and sale in the U.K. of staple fibres, filament yarns and textile monofilaments from polypropylene. Production at Kilroot should begin by 1963.

#### Nylon plant

Recently, British Enkalon Ltd., the Anglo-Dutch company jointly formed by British Enka Ltd. and A.K.U. of Arnhem, acquired a suitable site at Antrim to build a nylon factory. This plant will produce nylon-6 polymer from caprolactam, which will probably be imported from Great Britain.

Nylon yarn and moulding powder for the plastics industry will be the main products.

#### Viscose rayon

Courtaulds Ltd. have been producing viscose rayon fibre since 1950 in a plant at Carrickfergus, near Belfast. This plant, which is completely continuous, is one of the most modern of its kind in the world. Fig. 3 shows an aerial view. Carrickfergus makes one-eighth of the U.K. production of continuous filament viscose yarn and high-tenacity yarn for tyre cords. (This largely induced the Dunlop Co. to embark on the manufacture of tyre cords in Northern Ireland.) The raw materials, wood pulp, charcoal, caustic soda and sulphur, are all imported from abroad. Sulphur is shipped from the Lacq gasfields in France, wood pulp from Scandinavia and caustic soda and charcoal from Great Britain. Sulphuric acid is made on site, using two contact acid plants. Carbon disulphide is also made on site by the normal process of reacting sulphur with charcoal.

At the commencement of the process wood pulp is steeped in caustic soda. The resulting alkali-cellulose is shredded and carbon disulphide added to form a xanthate solution. This solution is dissolved with dilute caustic soda to form a viscose solution. This viscose solution is then ripened, filtered through conventional filter presses and passed through spinnerettes (platinum alloy dies with very fine holes or jets) into the spinning solution containing



Fig. 4. Neoprene sheet turned into 'rope' at Maydown



sulphuric acid, sodium sulphate and zinc sulphate. The filaments from each jet are then drawn together to form a yarn. The fibres are stretched, sometimes up to 80% of their initial length, in order to increase their strength and wound over a series of consecutive reels where they are washed to remove all impurities and dried. Finally the fibres are wound over bobbins. The complete winding time of fibre over a bobbin is 16 hr. for rayon filament yarn and 4 hr. for high-tenacity yarn. The total production of both types of yarn is about 360,000 lb./week.

### Petroleum refinery

A very important step in creating a potential petrochemical industry in Northern Ireland is the undertaking by British Petroleum to build a refinery in Belfast Lough. Work on the refinery should begin early next year and will probably be completed by 1964.

The refinery will have a capacity of 1.3 million tons of crude oil p.a. and will produce gasoline, kerosene, aviation turbine fuels, light and heavy diesel oils, fuel oil and liquefied petroleum gases. It will supply Northern Ireland market with Shell Mex and B.P., being designed to handle Middle East crude oil.

### Fertiliser production

The two Northern Ireland fertiliser manufacturing companies have been in existence for about 100 years—they are Richardsons Fertilisers Ltd., Belfast, and Ulster Fertilisers Ltd., Londonderry. These companies are owned by I.C.I. Ltd. (51%) and W. & H. M. Goulding Ltd. (49%). The fertilisers which they make and sell are handled by the selling company, Richardsons (Ulster) Ltd., and the indigenous manufacture is capable of supplying the present requirements of Northern Ireland in so far as superphosphate and compound fertilisers are concerned. Sulphuric acid is also supplied to the textile industry and for the manufacture of ammonium sulphate.

A modern factory is presently being built on the Belfast Harbour Estate by Richardsons Fertilisers Ltd. and will have a production capacity of 80,000 tons of concentrated fertilisers. These compounds will be based on ammonium phosphate. The new factory is expected to be in full production in the middle of 1962. The two other factories at Belfast and Londonderry will continue to produce low-grade compounds based on super-

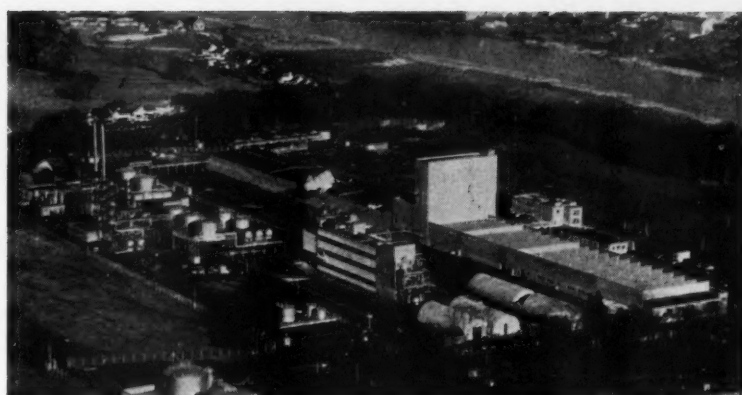


Fig. 5. Chemstrand's 'Acrilan' fibre plant at Coleraine

phosphate for as long as the demand justifies their existence. The trend, however, is undoubtedly towards the increasing use of more concentrated fertilisers.

### Conclusions

Ulster's chemical industry, as is evident from the above, has a large concentration of synthetic fibre plants. This is certainly not a fortuitous occurrence, but rather a desire by the government to build up a textile industry based on synthetic fibres which will inherit the place of the once flourishing linen industry.

The foreign chemical companies that are already established in Ulster are generally satisfied with the conditions, as is proved by their plans to expand production. They have in fact found the abundance of land, labour and water most conducive to further expansion.

It must be appreciated that, in order to establish an integrated chemical industry anywhere, it is necessary first of all to have facilities for producing basic inorganic chemicals such as caustic soda, chlorine, sulphuric and hydrochloric acid, etc. These chemicals are basic raw materials for practically all chemical processes and without their cheap availability it becomes quite expensive to operate other processes. Northern Ireland as yet lacks any such basic inorganic chemical industry—for this reason most local chemical companies are forced to manufacture their own basic raw materials and this inevitably entails increased capital expenditure, which might have been better invested in other ways. It would perhaps be wise now for the government to encourage some form of basic heavy chemical industry in order to pave the way for an altogether wider and more broadly

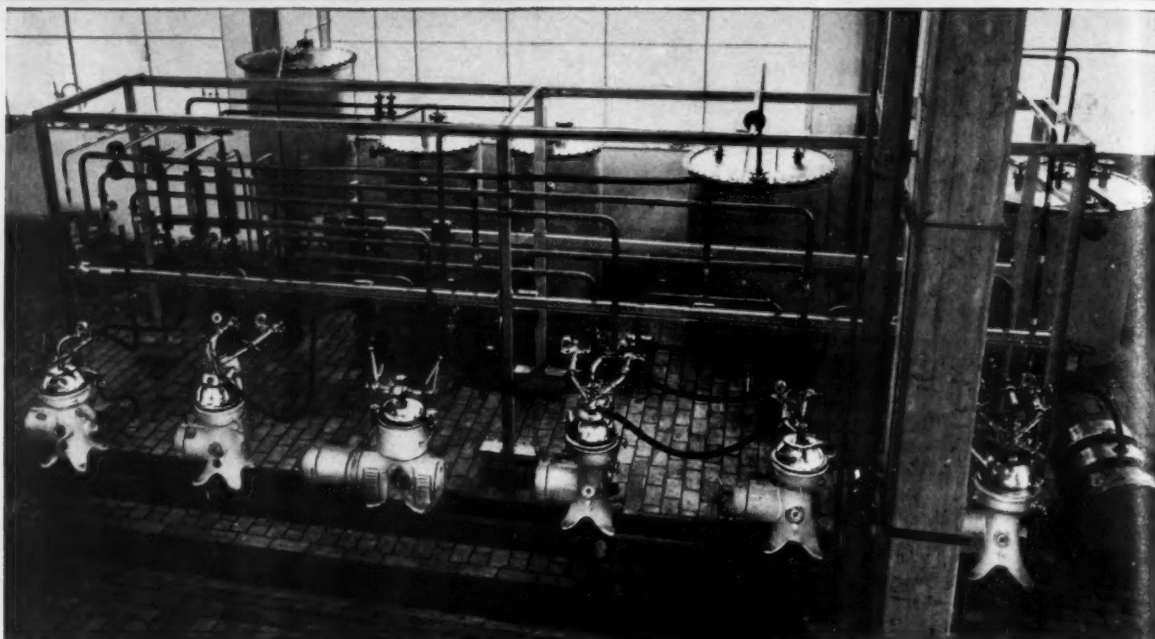
based chemical industry in the future.

It may, of course, be argued that the distance between Liverpool and Belfast is so small that chemical imports such as caustic soda do not have to travel a long way. Yet it inevitably ties existing and potential chemical manufacturers to the Midlands or Scotland, thus really hindering the chemical 'integration' of Ulster.

Perhaps an even more serious problem is that of technological education. At the moment there is a first-class university in Belfast, Queens University, with a time-honoured tradition in the medical and physical sciences. On the other hand, there are no technological faculties of equivalent standing. This forces young Ulstermen wishing to study technology and engineering to do so in Great Britain. It would therefore be timely for the Ulster government to establish a college of advanced technology in Belfast (nine such colleges are already in existence in England, Wales and Scotland and, due to the substantial government backing, they are extremely well staffed and equipped).

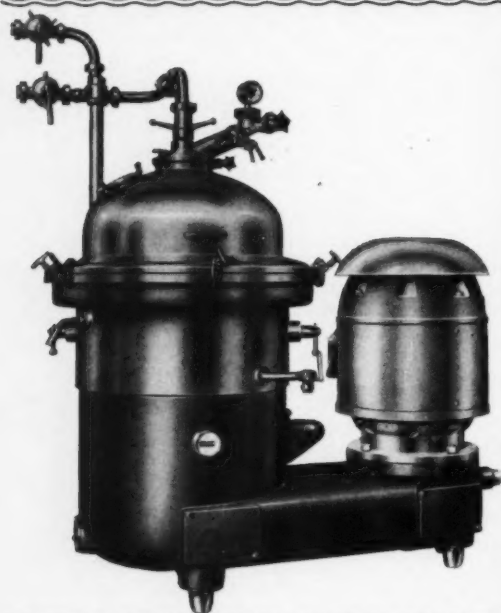
It is highly probable that those chemical companies already established in Northern Ireland would view such a college with the greatest favour and might even endow various departments. This would be one long-term method of solving the problem of technical staff recruitment for these companies, who are bound to find it increasingly difficult to induce technical staff from abroad to settle in Ulster. In particular, it would be important to establish a department of chemical engineering in Ulster as soon as possible. If these points are given due attention there seems no reason to doubt that Ulster's chemical industry should grow considerably during the next decade.

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# CENTRIFUGING

By T. A. Barker\*

*The annual review of centrifuging reports some progress in the theory underlying this unit operation. During the last year a variety of centrifuges have been offered by manufacturers for application in the process industries. Development of continuous basket centrifuges for the sugar industry is also reported. There are 45 references altogether.*

A SERIES of articles appearing under the collective heading of centrifugation equipment in *Industrial and Engineering Chemistry* provides a welcome addition to the published knowledge on centrifuges. Ambler<sup>1</sup> of the Sharples Corp. discusses centrifuge theory and develops a formula to describe the behaviour of materials to be separated in the gas centrifuge, the ultra centrifuge where molar kinetics have to be taken into account, and, most important from the point of view of this review, the industrial centrifuge.

For the comparison of geometrically similar centrifuges, the sigma value derived theoretically from Stoke's law is reiterated. This value is a function of a centrifuge bowl speed, inner and outer diameters, and in the case of the disc-type centrifuge, the number, spacing and half-cone angle of the discs. The ratio of the sigma value of one centrifuge compared with the value of another geometrically similar gives a direct scale-up factor for theo-

retical separating efficiency, although a modification to the theoretical value is suggested for disc-type centrifuges based on observation.

Also discussed in the theory section is liquid/liquid separation and the relationship between specific gravity differences and gravity disc selection.

The second article in the series by Sullivan and Erikson<sup>2</sup> of the De Laval Separator Co. is concerned with centrifuge design. An historical survey is included, together with illustrations of early continuous centrifuges. The development of the De Laval  $KQ$  value for the comparison of centrifuges is given and it is interesting to note that the expression is dimensionally identical to the modified sigma value now suggested. Other sections concern the mechanical aspects of the design of a rotating body, energy requirements and notes on metallurgy.

Smith,<sup>3</sup> in the third article under the general heading of centrifugation equipment, describes the wide range of

equipment available and details the duties for which they have been applied.

The equipment listed especially in the high-speed range is not comprehensive as no mention is given to fully hermetic centrifuges, nozzle machines with facilities for internal recirculation of the solids, nozzle machines with internal washing arrangements, and externally operated intermittent solid discharge machines with partial discharge characteristics.

The theory of centrifuges is also discussed in great detail in a paper given by Trowbridge<sup>4</sup> to the Institution of Marine Engineers. The sigma value is derived and discussed, and mathematical treatment is given to the problem of by-pass systems. The available equipment for various uses in the marine field is listed and the newer techniques of continuous fuel oil washing are described. In the subsequent discussion, interesting points were brought out including a description of the actual flow pattern of a liquid mixture in the disc pack of a centrifuge.

A very full survey of the methods available for the automatic control of centrifugals used in batch operations is given by Broadbent and Grimwood.<sup>5</sup> The main problem is automatic control of the feed which, in many cases, is the limiting factor which prevents fully automatic operation. Progress, however, is rapid in overcoming these problems and automatic control is likely to be extended to more difficult feed materials.

A review of centrifugal equipment with special reference to the processing of fat and soap is given by Kaufmann<sup>6</sup> and Flood<sup>7</sup> in a review article giving an up-to-date picture of the status of

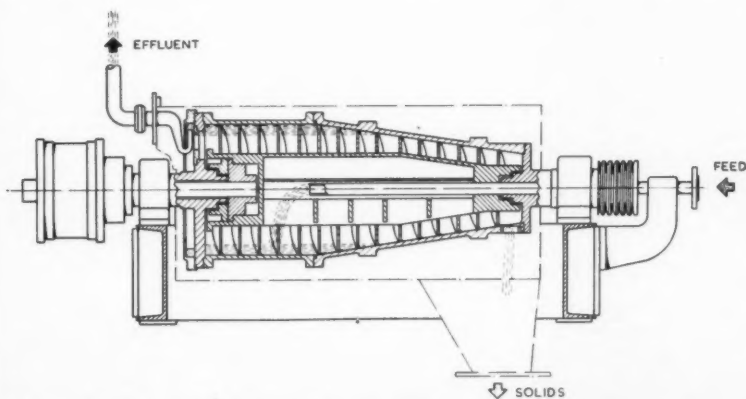


Fig. 1. De Laval desludger machine, showing paring device for pressure discharge of effluent

\*Alfa-Laval Co. Ltd.



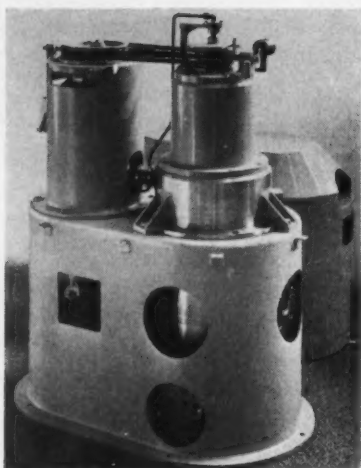


Fig. 2. Sharples 'Super-D-Canter' small-scale and pilot-plant centrifuge

centrifuge technology, especially in the U.S.A. A guide to the costing of centrifugals of all types is given by Smith.<sup>8</sup>

#### New machines

New machines have been offered by the major centrifuge manufacturers and provide very useful additions to the range of equipment available to process engineers.

The Alfa-Laval Co.<sup>9</sup> have introduced machines of the intermittent automatic solid discharge type with partial discharge characteristics. Previously the discharge cycle of the automatic discharge unit has entailed stopping the feed, a definite opening of the discharge ports to empty the bowl of both collected solids and interdisc liquid, followed by a distinct closing operation and, finally, re-opening the feed line. The partial discharge mechanism, however, permits the bowl opening to be controlled to small but definite periods which allow only the collected solid to discharge whilst retaining the interdisc liquid. This development has the advantage of permitting the solids to be discharged without turning off the feed, of reducing liquid losses with the rejected solids, and of allowing a truly hermetic machine of this type to be designed. The application of this design is somewhat limited to solids of a soft plastic nature and is finding application in the brewing and fruit juice industries.

For the chemical and petroleum industries, there are new versions of the various sizes of horizontal desludgers which are now available with paring devices for discharging the clarified liquid in a non-aerated con-

dition under pressure. The machines can also be arranged with seals for full gas-tight operation, as shown in Fig. 1.

Also introduced by the same company are two machines for the separation of spent acid and nitrated esters in the Gyttop process for the manufacture of nitroglycerine. The machines, designated the NGB 207-10 B and the NGB 209-10 B, are designed to have throughputs of spent acid and nitroglycerine of 600 and 900 kg./hr. respectively.

Sharples Centrifuges Ltd.,<sup>10</sup> following the introduction of their *Gravitrol* 2000, which was designed as a single-stage self-cleaning oil purifier, decided to make available the *Gravitrol* principle in centrifuges of other sizes for use with smaller engine installations.

The trend towards the use of centrifuges in pressurised systems continues and Sharples have, therefore, developed a P-600 *Super-D-Canter* suitable for pressure operation, as shown in Fig. 2. This centrifuge is designed for use on small-scale production units or on pilot plants. The P-600 *Super-D-Canter* is now available with all contact parts constructed from titanium.

The Sharples P-3000 high-capacity *Super-D-Canter* has also been developed in a pressurised form. The P-3000 and the P-1000 pressurised machines have been designed primarily for applications within the petrochemical industry, but they are also finding wide application in other fields.

The vibrator discharge principle has already been applied with success on the smaller Sharples *Super-D-Canters*, with particular reference to the separation stages involved in the manu-

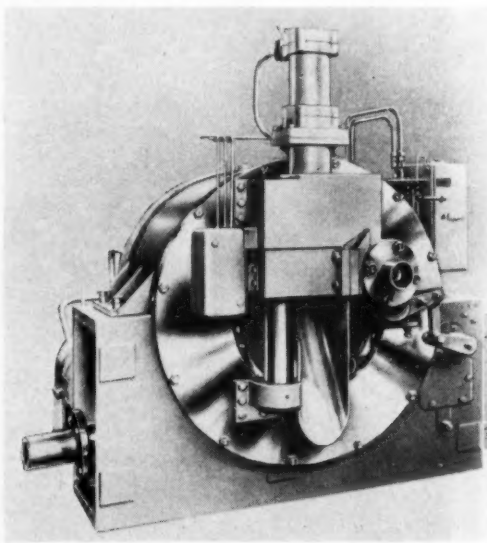
facture of a wide range of plastic materials. This principle has now been extended to the high-capacity Sharples P-3000 *Super-D-Canter*.

Thomas Broadbent & Sons Ltd.<sup>11</sup> have recently introduced two new chemical centrifuges designed to give increased production whilst saving labour and handling charges.

The 28-in. Type 81 centrifuge is for high-duty separation of freely filtering solids from mother liquors; the feeding, centrifuging and ploughing are all performed automatically at high speed. The drive is from a foot-mounted motor via a steel-cored rubber belt with moulded teeth meshing with toothed pulleys to give a positive transmission. Special attention has been given to basket design and machined drainage grooves are an important feature; recesses are provided for lining retaining rings and no backing lining is necessary (see Fig. 3).

An entirely new under-driven centrifuge, with hydraulic drive and labour-saving bottom discharge, known as the Broadbent Type 46A, is available in two sizes of 48 in. and 60 in. diameter of basket. This centrifuge is stable under liquor load, and the hydraulic drive gives a choice of feeding speeds to suit the product being treated. Should the machine be operated in a flameproof area, the drive unit can be remotely sited or made flameproof for mounting near to the centrifuge. Discharge is through the bottom of the basket by a manually or hydraulically operated discharging plough, and this ploughing operation is undertaken at a low, controlled basket speed to ensure minimum crystal damage. Mechanical brakes are avoided by

Fig. 3. A 28-in. type 81 centrifuge, introduced by Thomas Broadbent & Sons Ltd., for the high-duty separation of freely filtering solids.



using the same hydraulic system to reduce the basket speed and the self-balancing fume-tight cover is completely interlocked so that access to the basket is impossible whilst revolving above ploughing speed.

### Sugar

The most interesting theme running through the references to centrifuges in the sugar industry is the introduction of continuous centrifuges.<sup>12</sup> There is, however, a steady progress in the mechanical improvements to the traditional type of basket centrifuge.

The Hein Lehmann continuous centrifuge<sup>13</sup> has a conical basket rotating on vertical axis with the wide end uppermost. The separated syrup passes through the basket wall and the sugar crystals travel upwards and over the lip of the basket into a collecting chamber. In an account<sup>14</sup> given of trials in the U.S.A. using the same unit, it is stated that the continuous centrifugal is much more consistent and gives a better product than a poorly operated batch centrifugal, but that it is still impossible to produce the high-quality product that can be obtained from an expertly handled batch machine.

The pusher-type centrifuge is also employed for sugar centrifuging. The use of this type of machine is described in an article by Proskowetz<sup>15</sup> giving an account of the introduction of continuous centrifuges to a sugar plant in Peru over the past six years. Gusev<sup>16</sup> describes the potentialities of the pusher-type continuous centrifuge and gives a formula for calculating outputs to be expected from such units. Fig. 5 shows an Escher-Wyss pusher-type centrifuge.

### Oils, fats and soap

A steady increase in the use of centrifuges and centrifugal contactors in the edible oil and soap industry has been noted; the references generally under this heading are of a descriptive nature and give data on new and improved processes.

The De Laval *Centripure* process for continuous production of soap is described in articles<sup>17, 18</sup> and a patent.<sup>19</sup> The saponification is carried out continuously and is catalysed by recirculating soap back to the incoming lye and fat. Hermetic centrifuges are used for separating the soap in the subsequent washing stages and fitting stage.

In an article<sup>20</sup> concerning the control of continuous soap production, Palmqvist shows that the viscosity of the soap mixture is very dependent upon

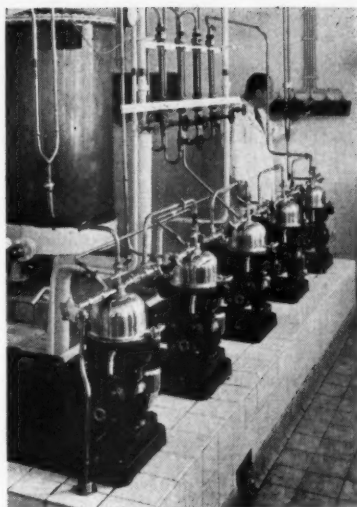


Fig. 4. Pilot-scale, multi-stage, counter-current extraction plant, incorporating Westfalia separators

the electrolyte content of the mass and provides a suitable parameter for process control. This method of control is employed in the De Laval *Centripure* process.

The continuous refining of crude coconut oil in a hermetic system is described in an article by Sullivan.<sup>21</sup> The plant consists of refining, water washing and vacuum drying sections. The centrifuges used in both refining and washing stages are De Laval 214 of hermetic design and are rated at 20,000 lb./hr. of fat.

In a survey<sup>22</sup> of recent progress made in the continuous refining of fatty oils, Braae describes the straight caustic, soda ash, short-mix and fully hermetic processes based on specially designed centrifuges.

The *Mini-loss* refining process<sup>10</sup> is a development of the Sharples continuous vegetable oil refining process designed to meet the requirements of refiners who only wish to handle a maximum of  $\frac{1}{2}$  ton/hr. of oil. The process is supplied as a package unit.

An account of a new cotton seed refining process based on an acetone miscella is given by Vaccarino.<sup>23</sup> The miscella is caustic-refined and diluted with hot water to remove the neutralised oil from solution. The oil and the water/acetone/soap mixture are separated using a centrifugal separator, the oil passed on to the next stage of the refinery and the acetone/water to a distillation column for separation and recirculation of the plant.

The degumming, caustic refining and water washing of soya-bean oil at the rate of 10,000 lb./hr. using two

Podbielniak centrifugal contactors is described and operating data given.<sup>24</sup> Reference<sup>25</sup> is also made to simultaneous soapstock separation and water washing using a Podbielniak centrifugal contactor when very encouraging results were obtained.

A plant for the rapid and continuous production of salad oil is described.<sup>26</sup> The plant consists of a miscella refining section employing a soapstock separator and a water-washing stage if required. The refined miscella is winterised and the precipitated stearine separated in a Sharples *D.G. Autojector*.

The use of horizontal-bowl screw conveyor centrifuges for the upgrading of inedible tallows is described in an article by Little and Downing.<sup>27</sup> Due to the fall in demand of inedible fats for soap making as synthetic detergents become increasingly important, other outlets have been found for tallow, but considerable upgrading has been required. A full description is given of refining techniques which include controlled dosing with small amounts of water, brine solution or trisodium phosphate solution.

Finally, a plant for the production of shredded beef suet is described and reference is given to automatic solid discharge centrifuges for the purification of the beef fat.<sup>28</sup>

### Chemical and process industries

The versatility of centrifuges is illustrated by the diversity of applications reported that may be grouped generally under the heading of the chemical and process industries.

The use of centrifugal separators in the starch industry is fully illustrated in descriptions of starch plants installed by two British companies.<sup>29-31</sup> The modern continuous starch plant is based essentially on nozzle-type separators with internal washing arrangements. Units of this type may be arranged in series to give three to four stages of counter-current washing. Also used are recirculating nozzle machines for the clarification of effluent waters and, in the case of the corn starch industry, the concentration of gluten separated in the starch washing process. A pilot-plant centrifuge for multi-stage counter-current extraction is shown in Fig. 4. It can be used for liquid/liquid separation, liquid/solid clarification and liquid/liquid mixing.

An article in *Die Starke*<sup>32</sup> describes the equipment offered by several centrifuge manufacturers and exhibited at the 1959 Starch Convention at Detmold. Another contribution<sup>33</sup> to the same journal describes recent

developments in starch centrifugals, including centrifuges for partially dewatering purified starch milks prior to thermal drying.

The process for the production of a modified starch is described<sup>34</sup> in which three centrifuges are used. A nozzle machine is first used for concentrating the suspension of modified starch flowing from the reactors, the effluent from this unit being passed through a continuous clarifier of the screw conveyor type to strip off remaining solids. The concentrates from both flow to a perforate basket centrifuge where final dewatering and washing takes place.

Centrifuges are becoming increasingly important in the fermentation industries, both for the separation of cultures from media and in subsequent solvent extraction processes. A Podbielniak centrifugal contactor is shown for the latter duty in a general-purpose fermentation unit recently installed.<sup>35</sup>

The continuous production of baker's yeast<sup>36, 37</sup> is fully described and the flow diagram of the washing stages using three nozzle-type separators is given with operating data.

Under the general heading of chemical processes a miscellanea of references appear. A process for the production of pure beryllium ingots uses a basket-type centrifuge for separating ammonium beryllium fluoride crystals in the purification stage.<sup>38</sup> Sharples Super-D-Hydrator automatic centrifuges are used for washing and drying processes in the production of Terylene,<sup>39</sup> and centrifuges operating under pressure for catalyst removal in various processes have been described.<sup>40, 41</sup> As already mentioned, the De Laval group have introduced a new range of separators for the explosives industry and its use is illustrated in a description of a new continuous nitration plant.<sup>42</sup> The use of a horizontal-bowl screw-conveyor-type centrifuge is described for the recovery of coal fines from a washery effluent.<sup>43</sup> A description is given<sup>44</sup> of the use of a Podbielniak centrifugal contactor for the extraction of petroleum feed stocks with phenol, and results are given which show that the removal of phenol solubles reduces carbon formation in distillation units and gives, generally, a higher yield of petroleum when catalytically cracked.

A full flow diagram is given<sup>45</sup> for the preparation of various grades of kaolin from natural deposits. A horizontal-bowl screw-conveyor type of centrifuge is employed for classifying the particles and subsequently a nozzle machine is used after coagulation for

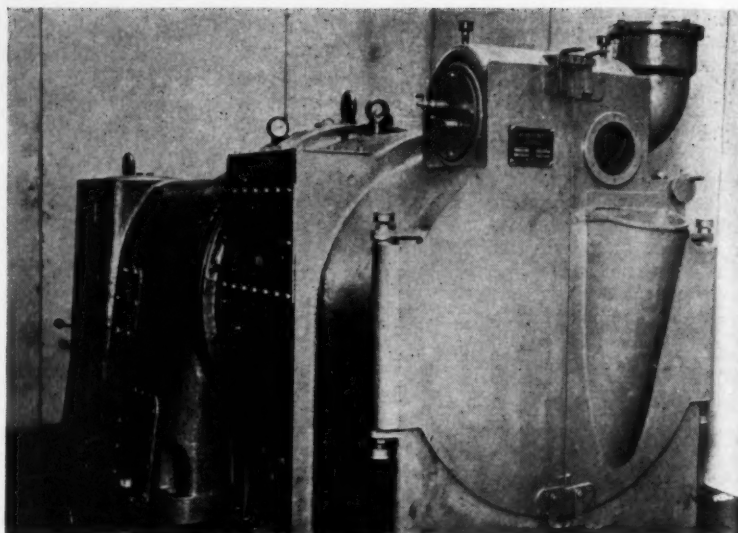


Fig. 5. Escher-Wyss pusher-type centrifuge

dewatering the suspension of fines prior to vacuum filtration and drying.

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#### Structural materials

'Structural Materials in Chemical Technology' is the title of volume 39 of the series of Dechema monographs which has been recently published. It has 140 illustrations and 19 tables, and contains the text of 16 lectures which were presented at the Dechema annual meeting, 1960. Each of the lectures is based on a different theme in the field of structural material techniques in chemical works and laboratories, and applications to important problems are discussed. Some of the subjects covered include the prevention of metallic corrosion, the prevention of boiler scale, and the use of acid- and heat-resisting substances in chemical technology.



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DECEMBER 13 Meeting on the electrical aspects of Hunterston nuclear generating station. Sponsored by the Institution of Electrical Engineers, to be held at Savoy Place, London, W.C.2.

DECEMBER 13 Meeting on power station optimisation. Sponsored by the Institute of Fuel, to be held at the Royal United Service Institution, Whitehall, London.

DECEMBER 14 Liversidge lecture on stereospecific polymerisation, by Prof. Bawn, to be given in lecture theatre, Royal Institution, Albemarle Street, London, W.1.

JANUARY 8 TO 12 International Heat Transfer Conference (a repeat of the conference held in Boulder, Colorado). Sponsored by the Institution of Mechanical Engineers and the Institution of Chemical Engineers, to be held at lecture hall, Central Hall, Westminster, London, S.W.1.

## Synthetic resins

Interest and development have stimulated each other in the recent past in the field of synthetic resins. A guide to new synthetic resins is the special feature of the December issue of **Paint Manufacture**. Articles include: Trimethylolpropane in Alkyds, by L. Grafstrom, A New Silicone Paint System for Heat and Corrosion Resistance, and Metal Finishes Based on Vinyl Organosols, by G. E. C. Mercer.

The following articles may be of interest to readers of CPE.

**Manufacturing Chemist**—The New Penicillins, by F. P. Doyle.

**Petroleum**—Naphthalene from Petroleum, by P. W. Sherwood. New Canadian Refinery Operating on Natural Gas, by H. G. Jarman.

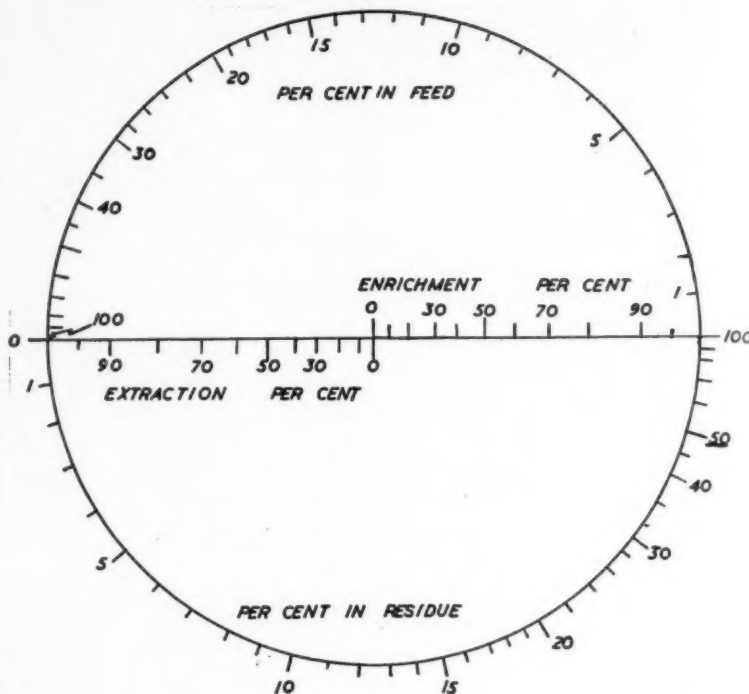
**Automation Progress**—Digital Computers: Trends in Use and Design, by T. Vickers. Key Factors in Applying Heavy-Duty Limit Switches, by R. L. Denison.

**Food Manufacture**—Special feature on Evaporation and Concentration.

Specimen copies of these journals and subscription forms are available from the Circulation Manager, Leonard Hill House, Eden Street, London, N.W.1.

# Extraction Efficiency

By G. E. Mapstone, Ph.D.



Extraction processes (including drying) are frequently controlled by analysis of the raw feed and of the processed material, the results being calculated to give the extraction efficiency as follows.

Let there be  $i\%$  of 'active' material present initially and  $f\%$  of 'active' material present finally when  $P\%$  is the extraction efficiency.

Then, 100 parts of initial raw material there are  $i$  parts of 'active' material and  $(100 - i)$  parts of 'inert' material. The extracted product will then consist of  $(100 - i)$  parts of 'inert' material and  $0.01i(100 - P)$  parts of 'active' material, whence

$$f = \frac{i(100 - P)}{100 - i + 0.01i(100 - P)}$$

This can be rearranged to give

$$P = \frac{100f}{100 - f} \times \frac{100 - i}{i}$$

The accompanying chart has been

designed to allow the rapid solution of this relationship.

N.B.—(1) If it is the 'inert' material that is extracted rather than the 'active' material, then the process will result in an enrichment of the residue.

(2) For the relationship to work, it is essential that either the 'active' or the 'inactive' fraction be removed by the process but not both. If both are extracted to different extents then the above theory is inadequate and the chart based on it cannot be expected to be accurate.

### Example

A sample of soil containing 26.0% of water is dried to a water content of 9.2%. What proportion of the water has been lost? Connect 26.0 on the initial concentration (upper) scale with 9.2 on the final concentration (lower) scale and read the extraction on the centre scale as 71% (calc. 71.16%).

# What's New



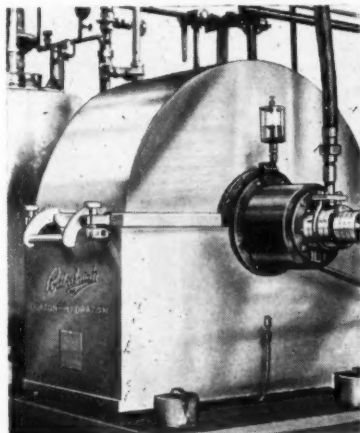
## in Plant • Equipment • Materials • Processes

CPE reference numbers are appended to all items appearing in these pages to make it easy for readers to obtain quickly, and free of charge, full details of any equipment, machinery, materials, processes, etc., in which they are interested. Simply fill in the top postcard attached, giving the appropriate reference number(s), and post it.

### Anti-corrosive plug lining

*Bascodur*, an anti-corrosive protective lining for plug, globe and angle valves, low-pressure gate valves and sight flow glasses, is now available in the U.K. through I.V. Pressure Controllers Ltd.

This lining is composed of a carbonaceous base agglomerated by means of a thermosetting resin. It is highly resistant to corrosion and is capable of resisting elevated temperatures. It



The podbielniak 'Duozone-Hydraxon' centrifugal contactor

is also usable in the presence of  $\gamma$  radiation up to a dosage of at least  $10^6$  r, subject to modifications which may occur if very strong chemical factors are added to the action of the radiation.

The plug, globe and angle valves are all suitable for pressures of 150 p.s.i. and temperatures up to 300°F.

CPE 1769

### Centrifugal contactor

Coconut oil is being efficiently refined by continuous methods at a plant in Panama operated by Industrias Panama Boston S.A. The plant uses a Podbielniak Duozone-Hydraxon compact rotating contactor which separates

the caustic-treated impurities from the crude oil and overcomes the emulsification difficulties encountered with conventional high-speed centrifuges. The contact takes place just long enough to capture the unwanted impurities, but not enough to break down the pure oil. Due to the success of the continuous process, Podbielniak are packaging refineries having capacities of one to five tank cars/day. These plants require one Podbielniak contactor and are complete in every detail including process equipment, piping and instrumentation. Plans are also available for plants designed to produce up to 12 tank cars/day.

CPE 1770

### Organo-silicate liquid

Hygrotherm Engineering Ltd. are now marketing an instrument-grade organo-silicate liquid, *Hyfil A*. This is said to have excellent thermal stability, a wide liquid range and low vapour pressure, making it a suitable thermofill liquid for thermostats and temperature-indicating instruments operated by fluid expansion.

It has a maximum-use temperature of 360°C.

CPE 1771

### Phosphating process

The Paints Division of I.C.I. Ltd. have developed a new, non-aqueous, phosphating process called *Kephos* which contains a sealer that is sufficiently corrosion resistant to protect work during transport or temporary exterior storage. Normally, work can be welded through the *Kephos* film, enabling items to be treated before fabrication. *Kephos* can be applied by brush, roller, spray or flow coating, and is said to enhance paint adhesion and resistance to rust creep, whilst improving the corrosion resistance of paint systems and eliminating possibilities of contamination by water-borne impurities.

CPE 1772

### Water monitor

Elliott-Automation Ltd. are marketing their high-sensitivity water monitor which measures and records the activity of solid radioisotopes dissolved in water. It consists of a sampling unit and an indicating unit. The sampling unit contains a Geiger-Muller tube surrounded by a bed of ion-exchange resin. Water is passed through the resin bed at a controlled rate and dissolved solids, including any fission products present, are retained in the resin.

CPE 1773

### Process control

Thompson Ramo Wooldridge Inc. have installed an RW-300 computer control system at the Tulsa refinery of DX Sunray Oil Co. to perform on-line, closed-loop control of a new



Applying a coating of 'Kephos', the new I.C.I. Paints Division process, on an air duct of A. Reyrolle & Co. Ltd.

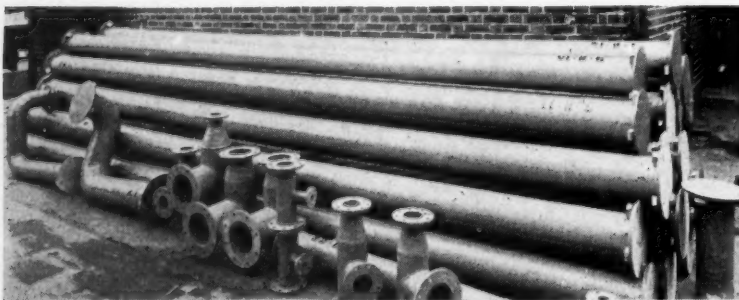


85,000-bbl./day crude oil distillation unit.

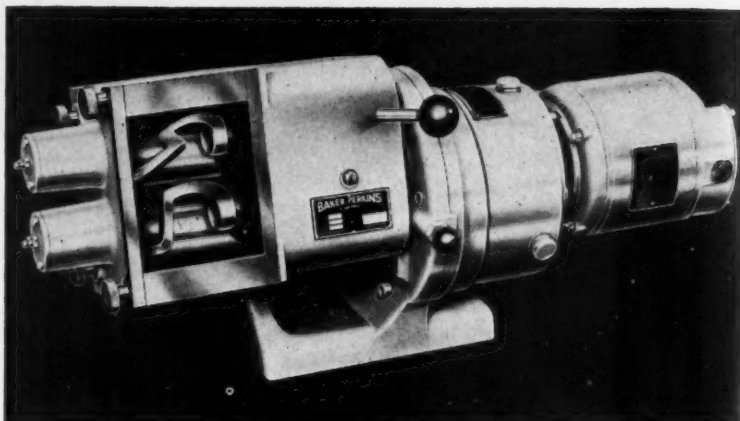
The RW-300 provides continuous and automatic control of the huge process by continually scanning 191 process instruments and adjusting 30 controller setpoints to maintain optimum efficiency. Such variables as temperatures, pressures, flow rates and stream compositions are checked every 10 min. and their readings are compared with predetermined limits stored in the computer's memory. Direct control is exercised over the distillation unit by automatically adjusting the appropriate controller setpoints, and means are provided for the operator to take over manual control of the unit if he feels such action is necessary. **CPE 1774**

### **Stainless-steel tubing**

Welding Technical Services Ltd. have designed their *Weltexa* system of stainless-steel piping to take a large range of fluids of varying corrosive action and to handle them at temperatures ranging from sub-zero to 700°C. and higher. The tubing is connected by special joints that inhibit corrosion and do not have internal protrusions. Use is made of a specially designed taft with mild-steel backing joint. Last year, the company, which carries out full-scale production of stainless steel, purchased the equipment for spirally welded tube making. Due to the new production techniques, it is claimed that the stainless steel has greater strength and durability, resulting in a reduction of wall thickness. Unlimited length straights are now offered and at reduced prices. Automatic welding is continuous and electronically controlled to a high degree of accuracy. All bore sizes are subjected to pressure tests, e.g. 3-in. bore is tested to 1,000 p.s.i. **CPE 1775**



Plastic Constructions Ltd.'s latest development in PVC pipelines for elevated temperatures and pressures, manufactured from extruded rigid PVC tube, mechanically wrapped externally with specially woven glass-fibre rovings and resin impregnated. The tubing can be supplied up to 18 in. in diam. and 20 ft. in length **CPE 1777**



A Baker Perkins 'Universal' laboratory mixer. A new range of mixers and masticators for rubbers, plastics and other viscous materials has been recently developed by this company **CPE 1778**

### **Pumps**

Arthur Lyon & Co. (Engineers) Ltd. recently exhibited two ranges of *Alcon* pumps at the Factory Equipment Exhibition.

*Alcon* self-priming centrifugal pumps can handle water and water containing small solids, petrol, paraffin, diesel and lubricating oils. The new *Alcon* 2-in. self-priming centrifugal pump is powered by a new Villiers D.270 four-cycle engine. It has an output of 10,000 gal./hr. with a total head of 104 ft. *Alcon* *Thames* range of single-stage centrifugal pumps, from 1 to 5 in., were also shown. Outputs range from 20 to 650 gal./min. at 2,900 r.p.m. to 15 and 700 gal./min. at 1,450 r.p.m. **CPE 1776**

### **Chromate conversion**

The Walterisation Co. Ltd. are marketing two new additions to their *Cromcote* series. These are for brass, zinc and newly galvanized steel surfaces. These will be known respectively as *Cromcote B.R.*, *Cromcote Z.C.*

and *Z.H.* All treatments are immersion processes which give a protective coating to their respective metal surfaces. *Cromcote Z.C.* and *B.R.* are diluted with 25 parts of water to make the operational strength. The work processed should be free of grease and corrosion products and the treatment time will normally be 1 min. at room temperature. Control of the bath is carried out by a straightforward titration of the processing solution, and chemical consumption of the bath is extremely low. Galvanized steel may be quenched direct into *Cromcote Z.H.*, enabling treatment to be carried out in the production line. **CPE 1779**

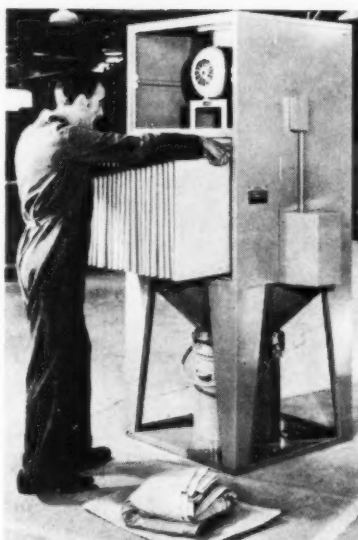
### **Calcium superphosphate**

Moritz Co. Ltd. are marketing their superphosphate den for the production of calcium superphosphate. This comprises a cylindrical container with central mandril rotating slowly at a variable speed on supporting rollers. The container is driven through a toothed crown wheel and pinion and kept centred by concentric rollers. The upper part of the container forming the den is closed by a floor which suspends a stationary portion and a mechanical cutter driven through a suitable reduction gear. The floor supports the automatic phosphate feeder, the acid feeder with measuring device and the phosphate/acid mixer.

The slurry hardens during the rotation of the den, forming a ring of superphosphate which regularly comes in contact with the revolving cutter. Both phosphate feeder and acid feeder are mechanically or electrically linked and controlled by a single drive. A Moritz den-type *Superbloc* is designed for small or medium outputs at 3, 6 or 10 tons/hr. **CPE 1780**

## Castings

At the Second Engineering Materials and Design Exhibition, Dewrance & Co. Ltd. demonstrated their method of hardfacing with *Endurance* alloys. The castings on show included such high-alloy castings as chromium-cobalt-tungsten, and *Endurance* heat- and wear-resistance materials. Castings in gunmetal, stainless steel and *Monel*, nickel-copper, nickel-molybdenum and nickel-silicon-copper alloys were also shown. These castings are available either as-cast or machined to individual needs. **CPE 1781**



A Dallow Lambert 'Uma Unimaster' unit dust collector. A one-piece filter pad assembly allows for easy removal, and greater spacing between filter pads enables more difficult dusts to be handled. A simplified shaker linkage and a new shaker bar result in improved cleaning of the filter element, and the electric shaker motor has a greater horsepower **CPE 1782**

## Packaged boilers

At the Northern Exhibition of Fuel and Power, Marshall Sons & Co. Ltd. showed their CB 300 and P 20 packaged boilers. The CB 300 oil-fired packaged boiler is rated at 10,350 lb./hr. steam from 212°F., and the P 20 oil-fired packaged hot-water boiler is rated at 670,000 B.T.U./hr. Marshall-built Cleaver-Brooks packaged boilers are four-pass horizontal fire tube units with 5 sq.ft. of heating surface per rated boiler horsepower. Integral forced-draught burner and controls are incorporated and the cooler return water is introduced at a point and in a direction which is said to provide the longest tempering path

attainable. It is also claimed that thermal shock is eliminated and uniform water temperatures are maintained, with the resultant greater thermal efficiencies. **CPE 1783**

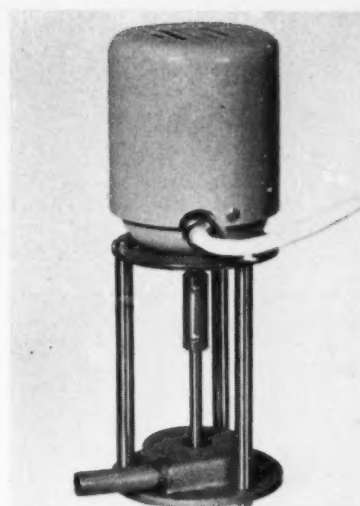
## Laboratory pumps

Jones & Stevens Ltd. have introduced a new small pump for use in the laboratory. The P.30 22-oz. pump has a flow rate of 2½ pt./min. for a water height of 4 ft. maximum. The P.50 27-oz. pump has a flow rate of 5 pt./min. for a water height of 4 ft. 6 in. maximum. The length of pump drive from the motor can be increased to provide a maximum immersion of 6½ in. to special order. The small motor directly connected to the pump impeller and of the single-phase, squirrel-cage induction type, has an input of either 30 or 40 W. The units are intended to operate from -20° to +110°C. The pump needs priming when first put in use. **CPE 1784**

## Sulphur dispersant

*Lubrol CB* is a new viscose spinning bath additive developed and marketed by the Dyestuffs Division of I.C.I. It has the advantage of possessing negligible affinity for cellulose. At the same time, in spite of its relatively weak cationic character (it is a substituted polyamine/ethylene oxide condensate), it has excellent sulphur-dispersing power and good stability under spin bath conditions.

The amount of *Lubrol CB* to be added depends on the type of product being made, varying from 0.2 to 0.8 kg./ton of product in the case of viscose rayon staple fibre to 1.5 to 3.0 kg./ton in the case of tyre cords. Intermediate quantities are suitable for cast sheet or for continuous filament viscose

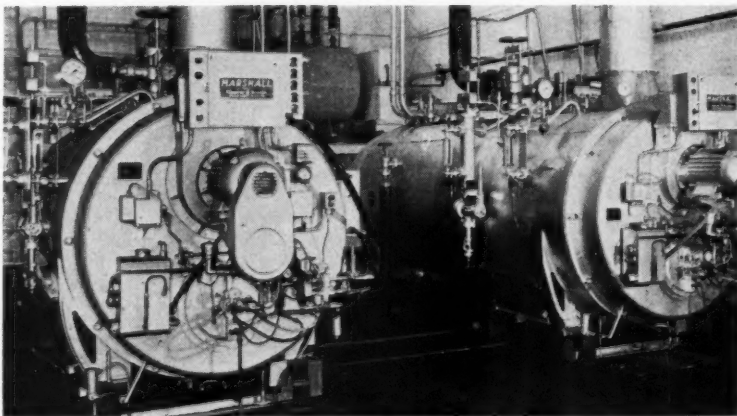


A Jones & Stevens small laboratory pump

rayon. *Lubrol CB* is said to inhibit corrosion of lead parts of the equipment and, in the tyre cord process, it can usefully be employed as a viscose coagulation retardant. **CPE 1785**

## Paste spray dryer

John Dalglish & Sons Ltd. are marketing their Model 2a paste spray dryer. With the aid of a stirrer and vibrator, the paste is fed to a variable-speed mono pump which forces it through a strainer to a specially developed nozzle. The system is automatic in operation and includes modulation of the inlet drying temperature by means of control over the outlet temperature. The dry product usually does not require further processing and when delivered from the spray dryer consists of a fine particle size of about 4 microns. **CPE 1786**



An installation of two typical Marshall 'CB' packaged boilers at the Greenbank Mill of William Birtwistle Allied Mills Ltd., Preston



# Nuclear Notes

## Nuclear waste evaporator

A nuclear waste evaporator has been designed and engineered by General American Transportation Corp. for storing low-level waste from reactors in remote locations. By reducing the volumes of waste, smaller nuclear reactors can be used and more readily transported. Only a 500-gal. storage tank is necessary with the evaporator which was built to specifications of the Martin Co., Maryland.

## Spent fuel shipment

The A.E.C. has proposed procedures and criteria to be followed by A.E.C. licensees to safeguard against accidental criticality, radiation exposure to individuals and the release of fission products during the shipment of spent fuel elements from reactors. This applies to solid irradiated fuel elements containing 2,000 or more curies of radioactivity in a single shipping container. Reactor licensees will be required to obtain Commission approval of cask design and shipping procedures.

## Nuclear plant proposals

The Commission of Euratom and the U.S. Atomic Energy Commission have invited organisations to submit second-round proposals by June 1962 for the construction of large-scale nuclear power plants to be brought into operation not later than December 1965. This invitation is the second issued to implement the 1958 agreement for co-operation between the United States and Euratom for the development of peaceful uses of atomic energy.

## Pakistan collaboration

The U.K.A.E.A. and the Pakistan Atomic Energy Commission are to develop their collaboration to promote the peaceful uses of atomic energy. Provision has been made for staff consultations as well as for assistance and advice on the uses of radioisotopes. The eventual supply by the U.K. of nuclear research and power reactors for civil uses in Pakistan is also envisaged.

## Irradiated foods

A technical meeting to evaluate the wholesomeness of irradiated foods was recently held in Brussels. The meeting was convened jointly by the Food

and Agriculture Organisation, the World Health Organisation and the I.A.E.A. This was a further step in the series of undertakings conducted by F.A.O. and other international bodies in the field of the use of nuclear energy in connection with food and agricultural products. The main purpose of the meetings was to evaluate the wholesomeness of foods preserved by ionising radiation and to make recommendations for legislation on the production and use of such foods.

## Hydrostatic moulding press

At the Second Engineering Materials and Design Exhibition, the U.K.A.E.A. showed a model by A.W.R.E. Aldermaston, of a press designed and made under contract to the A.E.A. by Foster Yates & Thom of Blackburn.

In the vessel of 24 in. internal diam. and 24 in. depth, high-explosive powders in a rubber bag are made denser by using hydraulic pressures up to 20,000 p.s.i. acting on the outer surface of the bag within the temperature range of 20° to 100°C. The model showed the main features of the vessel's associated plant, including the means provided for loading the powder and the fully interlocked control system.

## Reactor diagrams

Diagrams are now available of a further two reactors of the Atomic Energy Establishment, Winfrith. They

are NERO, a zero energy reactor designed to enable experiments to be carried out on a wide variety of reactor types and on the nuclear pro-reactors of materials used in reactors, and HECTOR, a reactor designed expressly for the use of the 'pile oscillator' technique for evaluating the nuclear behaviour of fuels, moderators and structural materials for reactors.

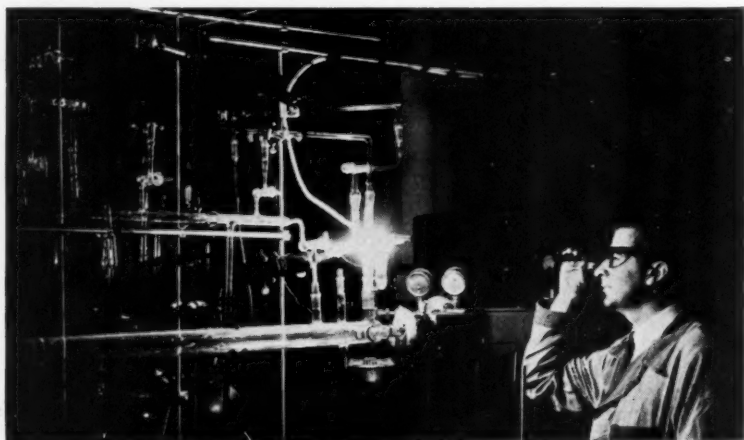
Particular attention has been paid in the design to achieving an extremely high degree of temperature stability since, in order to achieve the best accuracy from the oscillator measurements, it is necessary for the rate of temperature drift to be less than 0.003°C./min.

## Reactor licence

Mitsubishi Atomic Power Industries Inc. of Tokyo, will manufacture complete nuclear reactors and their associated auxiliary equipment under a licence and technical assistance agreement announced by Westinghouse Electric International Co. This covers closed-cycle water reactors as well as future types developed by Westinghouse.

## Proposed reactor

The American Atomic Energy Commission have received a report from the Advisory Committee on Reactor Safeguards concerning the reactor proposed by the National Bureau of Standards at Gaithersburg, Maryland.



A low-temperature, high-density plasma being used with spectroscopic equipment at Battelle Memorial Institute to study the effect of the plasma's intense heat on various chemical systems. It is hoped that reactions might be promoted, leading to materials with unusual high-temperature properties. Chemical systems to be studied at Ohio research centre include simple inorganic biradicals and possibly such organics as methane and benzene



The facility for which the National Bureau of Standards is seeking a construction permit, is a heavy-water-moderated tank-type reactor. The reactor would be operated initially at a power level up to 10 MW (thermal), although eventual operation at 20 or 25 MW (thermal) is contemplated. It will be used primarily for materials research.

#### Extended operation contract

The A.E.C. has extended for five years its contract with Phillips Petroleum Co., Oklahoma, for the operation of a number of facilities at the Commission's National Reactor Testing Station near Idaho Falls. Under the contract, Phillips will continue to operate the materials testing reactor, chemical processing plant, engineering test reactor, special power excursion reactor test plants and central plant facilities, and perform research and development work as assigned. The annual cost of the work for the five-year period is estimated at about \$27.5 million.

#### Increased cobalt-60 supply

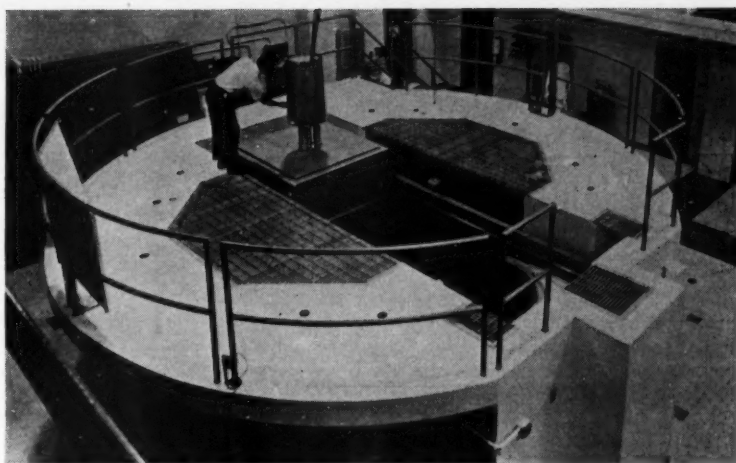
The Goodyear Tyre & Rubber Co. have tripled their supply of radioactive cobalt-60 in an intensified programme to explore the effects of nuclear energy upon rubber and plastics. The research programme aims at perfecting methods of vulcanising rubber by radiation, creating entirely new types of rubbers and plastics by using radiation as a polymerisation catalyst, developing rubber compounds not damaged by intense radiation and testing space projects.

#### Pulsing reactor

A TRIGA Mark-F reactor which produces split-second pulses of intense nuclear radiation under controlled laboratory conditions, has been developed by the General Atomic Division of General Dynamics Corp. It will be used in the U.S. Army's Diamond Ordnance Radiation Facility, Maryland, for studying the effects of intense radiation on electrical and electronic components. After a high-radiation pulse, the reactor restores itself automatically to a normal operating level without use of control rods or other mechanical devices.

#### British Nuclear Energy Society

On January 1, 1962, the British Nuclear Energy Society will be established and will succeed the British Nuclear Energy Conference which was established in 1955. The Institution of Civil Engineers has made its pre-



The TRIGA Mark-F 'pulsing' reactor

mises in Westminster available as a meeting place, and a regular programme of papers, lectures, symposia and informal discussions is being planned. The society will, like the conference, publish a quarterly journal and membership will be open on application to members of the constituent societies of the British Nuclear Energy Conference and to all who satisfy the board that they are 'actively engaged in the professional, scientific or technical aspects of the application of nuclear energy and ancillary subjects'.

#### Research advisory committee

Three groups of experts set up by the Euratom Research Advisory Committee are investigating the ways in which Euratom can co-ordinate and expand work being done in member countries in the fields of fast reactors, fuel reprocessing and biology. They also hope to put forward proposals regarding the second five-year research programme due to start in 1963. Fast reactor research will probably be a major feature of this second five-year programme. Negotiations are under way for Euratom to participate in the operation of the RAPSODIE reactor, and a contract has been signed with Belgonucleaire for the establishment of a research programme in neutron physics and the construction of fast neutron critical assemblies.

#### Reactor experiments

A symposium on power reactor experiments was recently organised by the I.A.E.A. This dealt primarily with certain scientifically advanced, but relatively untested, reactor concepts. No comparison of various reactor types discussed was attempted because con-

siderable research was still required on most of them at this stage. The VULCAIN concept was discussed; this is a reactor designed specifically to produce 20,000 shaft h.p. for merchant ship propulsion. It depends for control on variations of the temperature and composition of the moderator, rather than on neutron-absorbing control rods.

#### Calder Hall anniversary

Calder Hall recently celebrated its fifth anniversary. The eight Calder Hall and Chapelcross reactors have now accumulated between them over 24 reactor-years' operating experience. Heat and electrical output have exceeded design expectations, the magnox-canned uranium Calder fuel elements having withstood longer periods of irradiation than were expected.

As the result of a surplus of steam at Calder, Windscale space heating and process steam requirements will be met from the reactors. Eventually Calder reactor steam will take over entirely from the existing boiler houses, thus reducing the cost of site process steam by more than half.

#### Neutron reactor

A new nuclear reactor for research in the physics of neutrons, built by Soviet scientists, is now operating in the Joint Nuclear Research Institute at Dubna, near Moscow. The functioning of the reactor is based on plutonium rods and a disc with uranium-235 making 5,000 rev./min. The maximum capacity of the reactor is 3,000 kW.

The research being done with the new reactor is mainly concerned with the problem of transforming nuclear energy directly into electrical energy.

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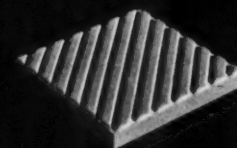
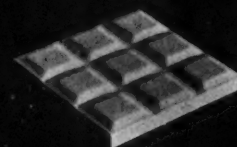
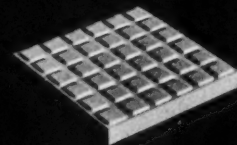
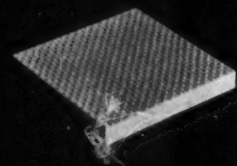
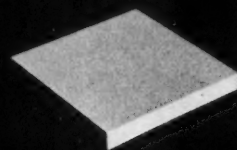
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# New Books

**Separations by Solvent Extraction with Tri-*n*-octylphosphine Oxide.** By J. C. White and W. J. Ross. U.S. Atomic Energy Commission NAS-NS 3102. \$0.75.

This monograph is one of a series on radiochemical techniques being published by the Sub-Committee on Radiochemistry of the Committee on Nuclear Science within the National Academy of Sciences-National Research Council of the United States. Despite the impressive official designation of the sponsors, their aim is essentially simple, namely to prepare up-to-date compilations of radiochemical information, procedures and techniques. In this they are to be warmly commended. The volume of work now being carried out, even in relatively specialised fields, is so large that it is almost impossible for any one person to keep abreast of developments from original papers. Monographs such as the one under review can do much to fill the gap.

Tri-*n*-octylphosphine oxide, usually abbreviated to TOPO, is a versatile solvent now commercially available in a relatively pure form in both the United States and Great Britain. It is a solid at ambient temperatures and is normally employed as a solution in an inert hydrocarbon, cyclohexane being considered the best for most cases. The authors commence with a review of the general characteristics of the solvent, covering diluents, the effect of the oxidation state of the element, etc., and then systematically consider its application to the elements in each group of the periodic table. In many cases, quantitative data is tabulated and there are also numerous graphs.

Considered within the scope of the original aim, the work is undoubtedly very successful and is a most useful compilation of the available data on TOPO. On the other hand, one is left with the definite impression that it has been written almost exclusively for the research radiochemist. Approaching the work as a chemical engineer, one immediately tends to ask whether there are any possible industrial applications for the solvent outside the laboratory. Would the problem of stripping referred to on page 4 then become a real difficulty? These questions are not answered and it seems a pity that the authors did not extend their treatment to cover any

possible large-scale industrial uses.

The production of the volume is generally of a high standard. The descriptive sections are lucid and the quantitative information readily found. The bibliography, however, is shorter than would have been anticipated for a work of this kind.

C. HANSON

**Dampfdrucktabellen nichtassoziiierender Stoffe.** By Dip.Ing. Ochley. Dechema, 1961.

This pamphlet consists of an introductory script and a series of tables of the boiling points of inorganic and organic compounds at various pressures, ranging from 1 mm. to 100 atm. These have been calculated by the use of the Clausius Clapeyron equation and those of Trouton, Nernst, Bingham and Kistiakowsky, etc.

This list of tables enables the determination of either the boiling point of vapour pressure of a compound, providing only that its boiling point at atmospheric pressure is known or can be determined, and that the compound exists at this temperature and pressure in a non-associated state. Where many determinations of vapour pressure have to be made frequently, as in chemical plant design, a series of tables of this kind can save much time-consuming search in the literature, and the accuracy of such tables is sufficient to be in accordance with the usual limits of accuracy of the plant design calculations themselves. The author claims  $\pm 1.5\%$  and a cross-check with some of the values reported in Perry's *Chemical Engineers' Handbook* seems to confirm that the accuracy is of this order.

No doubt for chemists and chemical engineers who are dealing with problems needing frequent and rapid access to vapour pressure data these tables would be of very considerable interest and importance, but as in the case of the various nomograms dealing with the same topic, it is normally not worth while to check possible inaccuracies in the table for the sake of infrequent calculations and, in this case, it is just as useful to use the basic formula and make a simple calculation for the vapour pressure required as part of the series of calculations involved in the whole problem.

Familiarity with the tables might

lead to some considerable time-saving where many of these calculations have to be made; but for English readers faced with a typescript in German the labour of familiarisation with the method of operation might prove to be just too much.

F. MOLYNEUX

**The Use of Oxygen in the Electrometallurgy of Steel.** By G. M. Borodulin. Translated by G. F. Modlen. 50s. net.

At the outset, it should be noted that the words 'electrometallurgy of steel' in the title refer simply to electric arc furnace steelmaking, but it must be stated that the subject is treated fully.

It is gratifying to be able to read in English, so soon after the original publication in 1959, an account of electric steelmaking procedure as currently practised in some well-known Soviet steelworks. It is doubtful whether an experienced melting shop manager will learn anything outstandingly new, but the very detailed presentation is almost certain to contain something of which he can make use, for the book is concerned solely with practical matters aimed at achieving the maximum benefit from the use of oxygen for rapid melting down and refining of the charge.

The first chapter deals very briefly with providing the furnace with oxygen, by direct pipeline, evaporator or bank of cylinders, and then describes in more detail the use of oxygen for melting down the remaining solid in a partly melted charge and indicates the precautions to be taken when carrying out the operation, as regards damage to the furnace and interference with the desired refining reactions. The type of watercooled lance for bath oxidation and the arrangements for its mechanised operation are well described and illustrated. The chapter finishes with a short thermochemical discussion of decarburising reactions with iron ore and with oxygen.

The second chapter, which forms the backbone of the book, is a series of detailed descriptions of the making of seven typical special steels, including stainless, transformer, high speed, ball bearing and plain carbon tool varieties. For each steel, the mode of operation, including charge and feed and finishing materials, is given and a full time-sheet showing consumption of materials and power, and yield, makes the procedure quite clear. It will be noted that great attention is



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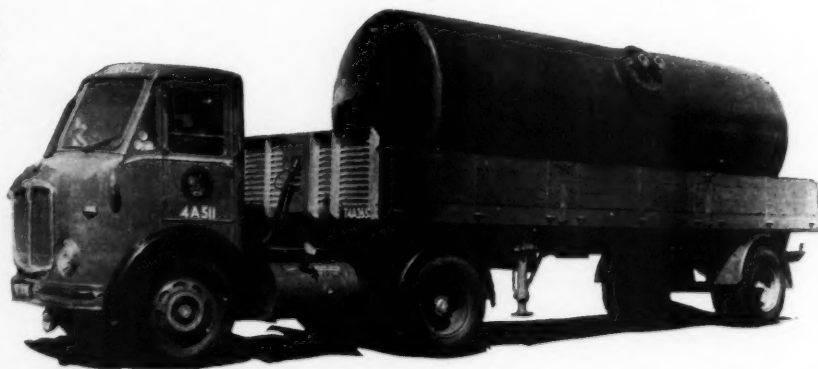
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given to the condition of the furnace before these steels are made, and to the roasting of additions to reduce hydrogen contents of the finished steels. As it now appears to be obligatory in the Soviet Union for all transformer steels to be vacuum treated, a description of the ladle degassing plant at Dneprospeetsstal works is included. Where appropriate, the differences between refining with oxygen and ore on the losses of alloying elements are given and explained.

An account of the use of oxygen in steelmaking would be incomplete without comment on the quality of the steel produced. This is considered in the third chapter and concerns the contents of oxygen, hydrogen, nitrogen and non-metallic inclusions at various stages of operation which do not differ essentially from those when ore is used for refining. Carbon and sulphur, which are generally somewhat lower when using oxygen, are also considered. The general conclusion is drawn that steels made with gaseous oxygen are in no way inferior, and sometimes superior, to those made conventionally.

The fourth chapter compares by detailed calculations the economics of making high speed and stainless steels with or without oxygen. Obviously the cost figures are given in roubles, but the corresponding English values could well be inserted.

The final two chapters deal with the construction of an automatic, remote-controlled charging machine, a pneumatic dispenser of conventional pattern for fettling, a spring clamp with pneumatic release for the electrodes, the influence of a sub-hearth electromagnetic stirrer and the protection of personnel.

The publishers are to be congratulated on producing a clear text and there is little need for their apology that desire for speedy availability caused them to use non-letterpress setting and photolithography. The translator has produced a text that reads well and is without those occasional clumsy passages that often characterise translations. The book will certainly be of value to melting shop staff, works metallurgists and metallurgy students. The latter will find the furnace time-sheets particularly instructive in their study of how steel is made in electric arc furnaces, though the price, even if it is justified by the cost of publishing translations for a restricted market, is likely to prevent them obtaining a copy of their own.

J. PEARSON

**Progress in Nuclear Energy, Series II, Reactors, Vol. 2.** Editor: H. R. McK. Hyder. Pergamon Press, 1961. 105s. net.

It may be asked why it is necessary in 1961 to produce a book which consists essentially of selected papers from the 1958 Geneva Conference on the Peaceful Uses of Atomic Energy. The answer lies in the overwhelming number of papers produced during the conference. Even to the established worker searching for information in his own field, this mass of data is somewhat bewildering; to anyone newly entering the field, it is much more so.

This volume contains an assortment of review papers from the 1958 conference, mainly concerned with experimental and computational reactor physics. Since each paper has a liberal collection of references and the volume, as a whole, has a useful index, it is now possible to collect information on particular topics without too much difficulty.

Books such as this are worthy rather than exciting. They can be safely recommended to anyone new to the reactor business and needing a guide to the proceedings; there is the further advantage over the original volumes that they can be carried without discomfort.

P. J. GRANT

**Carbon-14 Compounds.** By John R. Catch. Butterworths, 1961. Pp. vii + 128. 30s. net.

This excellent little volume is sponsored by the U.K. Atomic Energy Authority, and in it the author has admirably fulfilled his twin aims of a guide to the literature and to the uses of carbon-14 compounds.

The subjects discussed are the production of C-14, chemical syntheses, biological methods of labelling, peculiar features of C-14 compounds (*e.g.* isomerism, isotope effects and radiation decomposition), analysis, measurement of C-14 and safety precautions. Each chapter gives a concise and often

stylish account of the fundamentals, which make for fascinating reading for novice and expert alike. The total of some 600 references in such a slim volume gives an indication of its thoroughness; an author index would have been welcome.

The layout is excellent. Although the price is high, the book is unreservedly recommended.

P. H. GORE

**Direct Methods in Crystallography.** By M. M. Woolfson. Clarendon Press, Oxford, 1961. Pp. 144. 30s. net.

The object of this book is to describe the general principles of the so-called direct methods and techniques and their application in the determination of crystal structure, *i.e.* the interpretation of diffraction patterns in terms of atomic arrangements. As the author points out, the days of the solution of such problems by trial and error procedures are rapidly drawing to a close. These 'indirect' methods consisted essentially of postulating a possible crystal structure and then comparing the calculated with the observed intensities. Various graphical aids are available to help in this work.

The 'direct' methods refer to those which attempt to derive the phases of the structure factors directly, by mathematical means, from X-ray diffraction data. Once the mathematical problem has been formulated, the aid of the computer can then be enlisted to effect the desired solution. These direct techniques, therefore, represent an important step forward. But there is another side to the coin—from an educational point of view, the direct methods lack the visual picture so necessary for the student.

The book is divided into two parts. The first is devoted to a description of the principles and relatively simple applications of the direct methods. The second gives a more advanced treatment of the techniques which involve the use of an electronic computer.

The reader is expected to have a firm grasp of the principles of crystallography and a reasonable mathematical ability. Indeed the author goes to some trouble to suggest that this book should not be regarded as a suitable approach for the newcomer.

This volume is very neatly produced, as are most books coming from the University Press, and it is offered at a reasonable price.

J. W. MULLIN

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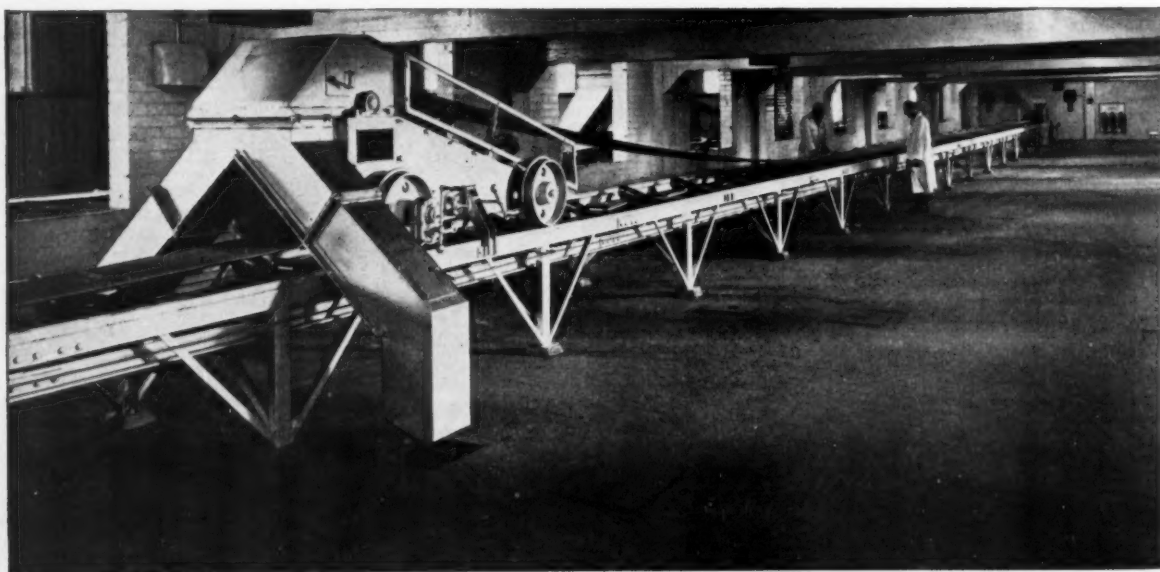
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# Orders and Contracts

## Electrical recording instruments

It is announced that Elliott Bros. (London) Ltd. are to sell, in the U.K. and Ireland, the complete range of electrical recording instruments made by the Esterline Angus Instrument Co. Inc., U.S.A. These recorders measure and record amperes, volts, watts, frequency, power factor, events, speed, position, motion, pressure and vacuum. They are said to be extremely robust, accurate and reliable instruments.

## Magnesium plant

The Power-Gas Corp. Ltd. have been appointed main contractors by Magnesium Elektron Ltd. for the engineering of a new plant to produce 5,000 tons p.a. of magnesium at Hop-ton, Derbyshire. This will make the U.K. largely independent of magnesium imports from overseas.

The plant will extract magnesium of 99.9% purity from local dolomite by a reduction process not hitherto operated commercially. The total value of the order is expected to be about £2 million.

## South African refinery

Foster Wheeler Ltd. have been awarded a contract for the design, engineering, procurement and construction of a 70,000-bbl./day. refinery to be built near Durban, Republic of South Africa.

This refinery will be constructed for South African Petroleum Refineries (Pty.) Ltd., in which a company of the Royal Dutch Shell Group of companies and British Petroleum Co. Ltd. each have a 50% interest. It is intended that the refinery will go on stream by January 1964.

## Titanium oxide plant

Laporte Titanium Ltd. have awarded to the Bechtel organisation the overall contract for engineering and construction of the titanium oxide plant to be built for them at Bunbury, Western Australia.

The plant is designed to produce 10,000 tons p.a. of titanium oxide pigment.

## Linear accelerator

The European Atomic Energy Community (Euratom) has signed a contract with the Compagnie Generale de Telegraphie Sans Fil (C.S.F.) for the supply of a linear accelerator. The apparatus is intended for the laboratories of the Central Nuclear Measure-

ments Bureau set up by Euratom at Geel, Belgium.

## Fertiliser granulating plant

Fisons Fertilizers Ltd. have awarded McKee Head Wrightson Ltd. a contract for the detail design, supply and erection of the mechanical components of a new compound fertiliser granulating plant at their Cliff Quay Works, Ipswich.

McKee Head Wrightson is a company jointly owned by Head Wrightson & Co. Ltd. and Arthur G. McKee of Cleveland, U.S.A.

## Gasoline plant

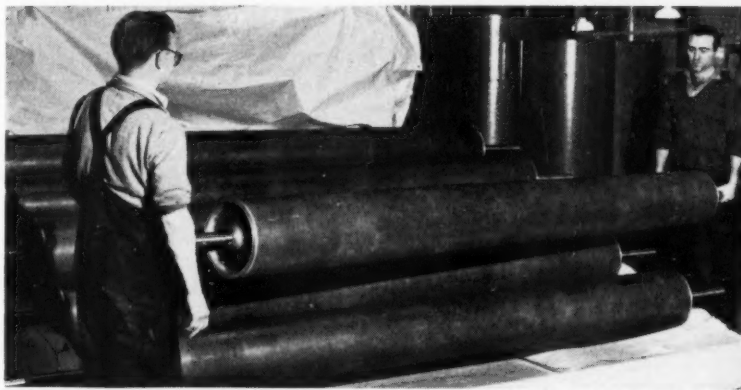
Edwin Danks & Co. (Oldbury) Ltd., a subsidiary company of Babcock &

a thickener and centrifuges and is to be installed for the original 30-ton kaldol furnace.

## Turbo-generator

The General Electric Co. Ltd. recently received an order from the Reed Paper Group for a 5-MW pass-out geared turbo-generator and the associated condensing plant, valued at approximately £125,000. It will be installed alongside two existing G.E.C. sets in the Group's Empire Paper Mills at Greenhithe, Kent.

Designed for inlet steam conditions of 600 p.s.i.g. and 800°F., the turbine will exhaust to a vacuum of 28½ in. Hg. It will be fitted with a pressure-controlled passout for delivery of up to 80,000 lb./hr. of process steam at 20 p.s.i.g. The condensing plant will be manufactured by Hick Hargreaves & Co. Ltd.



An order for resin-bonded rollers has been received by the Insulation department of Ferranti Ltd. from Wiener Maschinen Fabrik, manufacturers of paper-conditioning machinery in West Germany. Although originally designed for use in the transformer industry—mainly for insulation purposes—resin-bonded tubes have recently been developed for mechanical applications

Wilcox Ltd., have secured in collaboration with two well-known American design organisations the main contract, worth over £1 million, for the supply of a gasoline plant and associated well-head equipment for Technometal Export-Import, Yugoslavia, which is acting on behalf of the Naftagas concern in that country. The plant is to produce gasoline and industrial gases from the natural gas which is found in parts of Yugoslavia.

## Gas-cleaning equipment

Peabody Ltd. have obtained a contract for the gas cleaning and recovery equipment for the steelmaking kaldol plant at Stora Kopparbergs Domnarfvet works in Sweden, where hot metal is refined by oxygen in a rotary furnace.

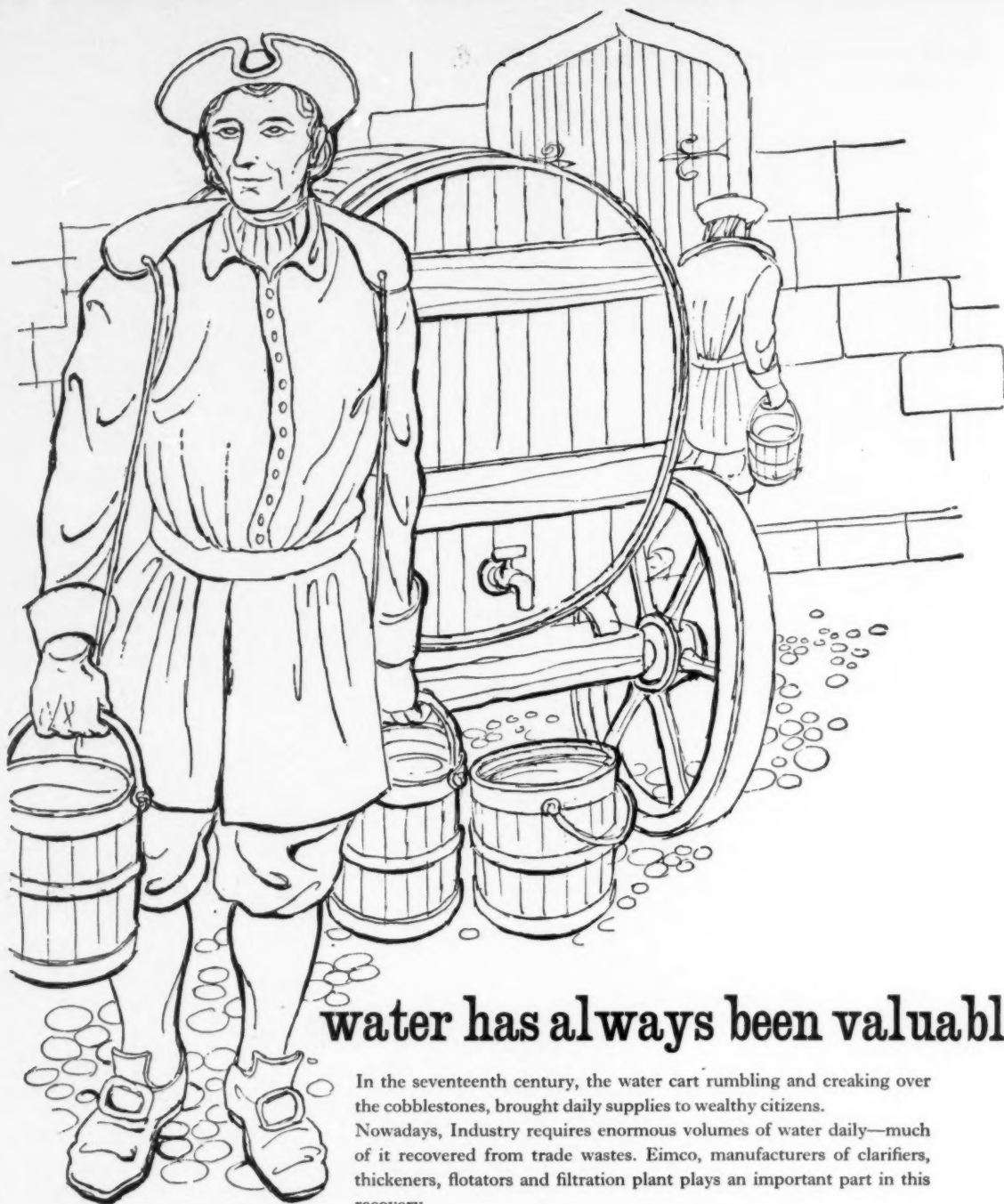
The contract for complete design, manufacture and erection, includes the supply of a Peabody wet gas scrubber,

## Tyre factory

Simon Handling Engineers Ltd. announce that they have signed a contract with Techmashimport, the Soviet trade organisation, valued at over £1.8 million. The company is to supply complete machinery and equipment for a new tyre factory to be built at Voljsk, near Stalingrad. The company's total orders received during 1961 for this type of work for the Soviet Union are valued at over £2 million.

## Water treatment plant

Head Wrightson Processes Ltd. have been awarded a water treatment plant contract by Esso Petroleum Co. Ltd., worth approximately £150,000, for their Fawley refinery. The plant is the first stage of an expansion of the boiler feed-water facility and will initially handle 1 million gal./day with an expected final flow of 4 million gal.



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# CPE Company News

## German subsidiary

B.T.R. Industries Ltd. have, in anticipation of Britain's entry into the Common Market, formed a wholly owned subsidiary in Cologne, B.T.R. Industries GmbH. This new company will, at the outset, manufacture *Hi-Flex* hydraulic hose assemblies to meet British, American, German and French standards and sizes.

## Sulphamic acid

Sulphamic acid is now being supplied by Albright & Wilson (Mfg.) Ltd. from what is thought to be the first plant in the U.K. to produce in bulk. Marchon Products Ltd., who are manufacturing the acid, are using  $\text{SO}_3$  from their anhydrite kilns on the same site. The crystalline strong acid is easy to transport and store, and safe to handle. It is valuable in dyeing processes and as a descaler of metals.

## Automation analysis department

Elliott Bros. (London) Ltd. have created an automation analysis department within its data processing group. This has been formed to overcome the lack of available knowledge regarding the mathematical nature of industrial processes which, it is said, is hindering the extensive introduction of complex automation systems into this country.

## Lead development committee

The European Lead Development Committee has been formed to coordinate and expand promotional work throughout Europe. The L.D.A., London, will be responsible for the secretarial work of the new committee under the guidance of a steering group comprising France, Germany, Italy and the U.K.

## Polypropylene filament yarn

I.C.I. Ltd. have started production of *Ultron*, their new polypropylene filament yarn, on a pilot plant at Wilton. The first full-scale plant, with a capacity of 5 million lb. p.a., will commence production at Wilton by the end of the year, and extensions will be built as required at the company's new site at Kilroot in Northern Ireland.

## Water purification company

Combustion Chemicals Ltd. have announced the formation of a subsidiary company, under the name of Water Engineering Ltd.

The new company will manufac-

ture, under licence, the range of water clarification and purification plant marketed on the Continent by Cie. D'épuration et de Traitement des Eaux de Paris.

The present range comprises an instantaneous separator, high-speed clarifying filters, water sterilisation, H.OH total demineralisation, H.Na pre-treatment and a continuous purge-type water separator.

## Polymer plant

Marbon Chemical Division of Borg-Warner Corp. have purchased a plant site at Grangemouth, Scotland, for construction of a plant to produce *Cyclocac*-brand polymers and other synthetic resins. The new plant will be somewhat smaller initially than the principal Marbon plant at Washington, U.S.A. The overall cost will be less than \$5 million.

## New joint company

Cambridge Instrument Co. Ltd. and Istrumenti di Misura C.G.S. SpA., Italy, announce final agreement for the formation of a new joint company, Cambridge-C.G.S. SpA. The issued capital of the new company, in which each parent organisation has an equal interest, will be 300 million lire, and the factory will be located at Casoria, adjoining an existing production plant of Istrumenti di Misura C.G.S.

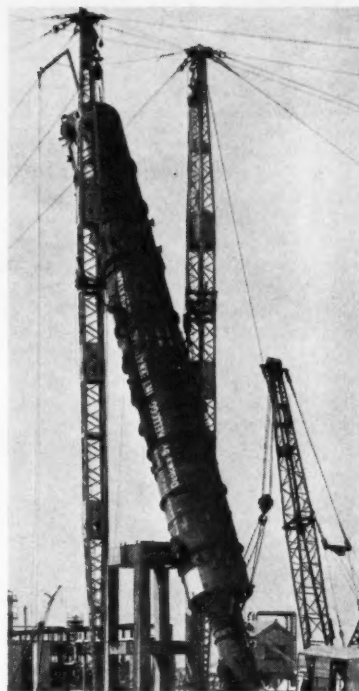
Cambridge - C.G.S. will initially manufacture electronic and galvanometric indicators and recorders for a wide range of applications, and associated control equipment. These will be adapted to meet the requirements of the Italian and neighbouring markets.

## Trichloroethane plant

I.C.I. have completed a plant at Widnes to make 1,1,1-trichloroethane, a solvent not previously manufactured in the U.K. The new solvent will be sold under the trade mark *Genklene*, and extends the range of chlorinated solvents already made by the General Chemicals Division of I.C.I.

*Genklene* is non-inflammable, of medium volatility and low toxicity—specially suitable for cold cleaning. The solvent can be applied by wiping, dipping or spraying, and contaminated solvent can be purified by distillation for re-use if required.

It is expected that it will also become a solvent in adhesive compositions, in the formulation of cutting oils.



A steel fractionating column weighing 54 tons being raised at Mobil Oil's Coryton Refinery where it will be used in the processing of crude oil. It was made at the Greenwich works of G. A. Harvey & Co. Ltd. to the design and order of Kellogg International Corp. and has a mainshell 109 ft. long and 10 ft. diam.

## Water treatment equipment

Water treatment equipment designed by William Bobby & Co. is to be produced and marketed in Australia under an agreement with the Magnus Chemical Co. (Pty.) Ltd. The concession applies to the whole range of Bobby plant except where electro-dialytic methods are involved.

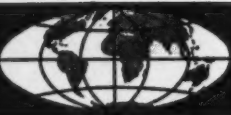
This is the second agreement of its kind that William Bobby have reached with an overseas company this year. A South African firm, Watermasters (Pty.) Ltd., have already begun production of Bobby plant.

## Polyethylene dumping

Monsanto Chemicals Ltd. have announced that they are collaborating fully with I.C.I. Ltd. in seeking legislation against the 'dumping' of foreign-made polyethylene in Great Britain. Jointly with I.C.I., they have made formal representation to the Board of Trade.

Monsanto's current annual production of polyethylene is in excess of 17,000 tons and plans have been announced of an expansion of production to more than 25,000 tons by 1963.



**AUSTRALIA****Oil search**

Legislation designed to speed up the search for oil in Australia has been passed by the Senate. The South Australian government has formed a new branch in the State Mines Department to work solely on the search for oil and an American oil specialist has been appointed as consultant. It was also proposed that the Bureau of Mineral Resources should work to locate 30 to 40 drilling sites a year.

**SWEDEN****Steam accumulator**

A giant cylindrical steam accumulator, approximately 30 m. long and 3.4 m. in diam., was recently shipped by rail from the Degerfors steelworks of the Uddeholm group to the Swedish Atomic Energy Co.'s uranium extraction plant at Ranstad.

**International research centre**

An international research centre costing £75,000, is being planned for Uppsala by the university's student body and the Royal Society of Sciences of Uppsala. The centre will accommodate 140 foreign research workers.

**SPAIN****Hydrogen peroxide plant**

Laporte Chemicals Ltd. have entered into an agreement with the Spanish company, Peroxidos S.A., to provide technical assistance and advice on the construction of an autoxidation hydrogen peroxide plant near Saragossa in Spain. The initial capacity of the plant will be 1,000 tons p.a. of

hydrogen peroxide and production is planned to start in 1963.

These arrangements have been made in conjunction with Foret S.A. of Barcelona, who since 1934 have manufactured hydrogen peroxide by an electrolytic process licensed by Laporte.

**BULGARIA****Steel works**

The design has been approved for the erection of a metallurgical group of enterprises in Kremikovtsi. This will include the erection of two blast furnaces capable of producing over a million tons of cast iron annually, a steel shop for a total annual production of over a million tons of steel, and mills with an annual capacity of 1 million tons of rolled stock.

**DENMARK****Ammonia plant**

The Power-Gas Corp. Ltd. have been appointed engineering contractors for the building of a complete ammonia plant to be erected at Grenaa in Denmark. This plant forms part of a new fertiliser factory for Dansk-Norsk Kvaelstoffabrik of Copenhagen. The value of the completed plant will be nearly £2 million.

**New company**

Nordisk Gulf-Gas A/S, a joint Danish-American company, has recently been formed. The company will acquire the propane/butane/liquid petroleum gas business of Nordisk Flaskegas A/S which now operates in Denmark. Gulf Oil Corp. through Warren Petroleum International Corp.,

a wholly owned subsidiary, holds a substantial interest in the new company. The main source of supply will eventually be the Gulf refinery now under construction at Stigsnaes, Denmark.

**UNITED STATES****Acetylene plant**

Société Belge de l'Azote et des Produits Chimiques du Marly (S.B.A.) have just concluded an agreement with Tenneco Chemical Co., U.S.A., for use of S.B.A.'s acetylene process in a new plant, which will produce 100 million lb. p.a. of high-purity acetylene, to be erected near Houston, Texas. Engineering, procurement and construction have been entrusted to the M.W. Kellogg Co., New York.

**Hydrogen fluoride plant**

The Kaiser Aluminum & Chemical Corp is undertaking the immediate construction of a \$6-million plant for the production of hydrogen fluoride and fluorocarbons. The new facilities will be built adjacent to the present alumina and caustic-chlorine plants at the corporation's Gramercy, Louisiana, works. Operations are scheduled for the latter part of 1962.

**ISRAEL****Dead Sea works**

Within the next four years, it is expected that production of potash at the Dead Sea works will be increased to 600,000 tons and that of bromine to 10,000 tons p.a. Erection of a plant for the annual production of 20,000 tons of various bromides and of a plant for the annual production of 75,000 tons of magnesite is envisaged. Plans for the production of Dead Sea minerals were stated to be well advanced. In addition, a plant for the manufacture of copper sulphate, and a plant for the production of alumina, are being constructed.



A battery of Audco valves shown in operation at Kuwait Oil Co.'s No. 15 Gathering Centre at Raudhatain. Commissioned in 1960, it handles production from 27 North Kuwait wells. By the end of the year throughput at this Gathering Centre was averaging 160,000 bbl./day of crude oil

**£ s d****CHEMICAL PLANT COSTS**

Cost indices for the month of October 1961 are as follows:

Plant Construction Index: 185.8

Equipment Cost Index: 174.9

(June 1949 = 100)

**£ s d**

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